THE PRODUCTION ENGINEER

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

JULY 1961

THE PRODUCTION ENGINEER

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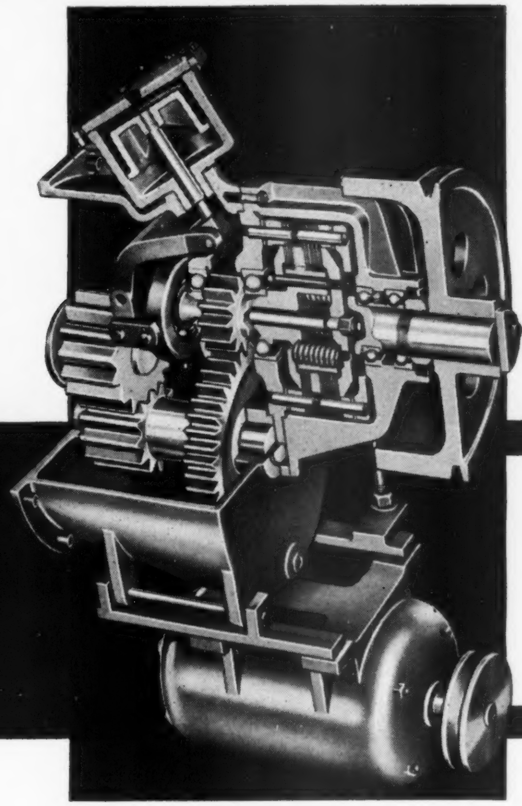

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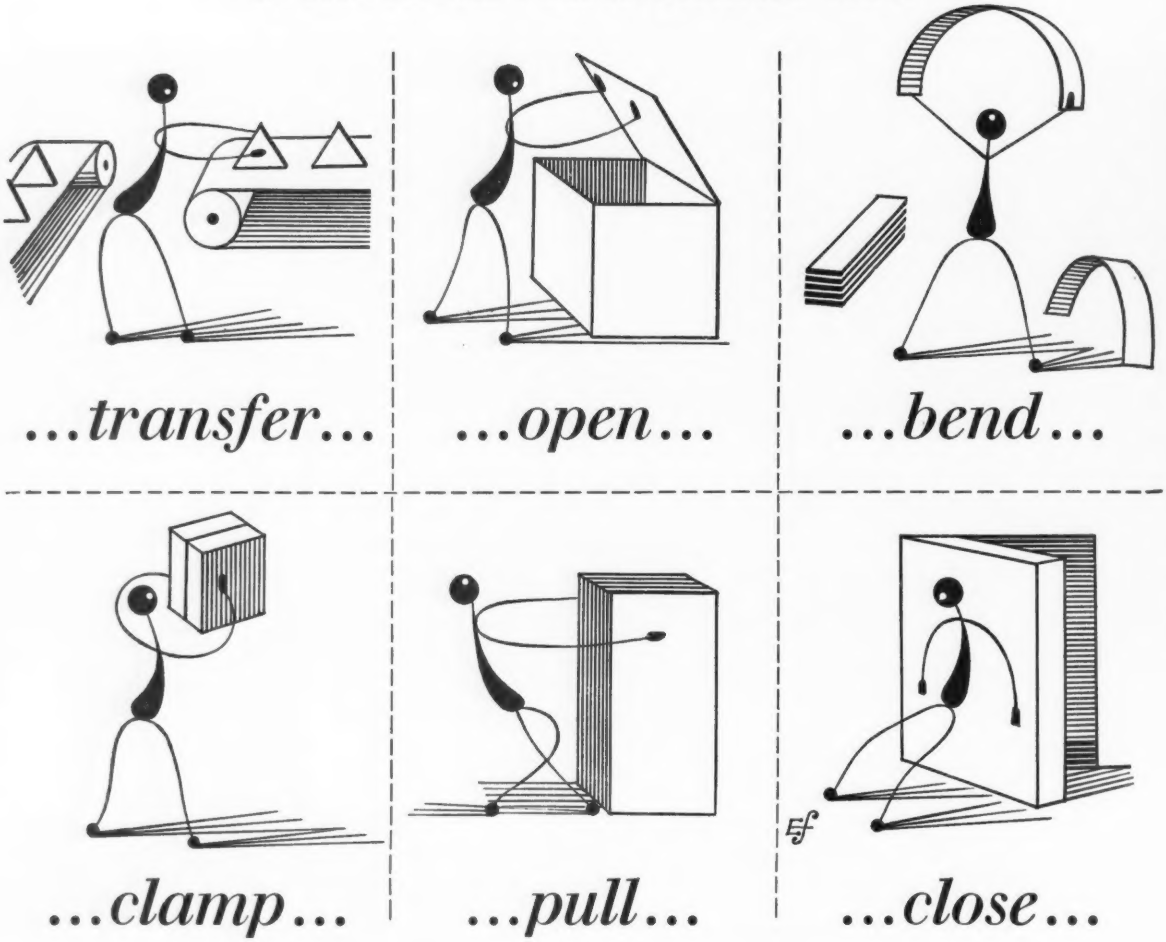

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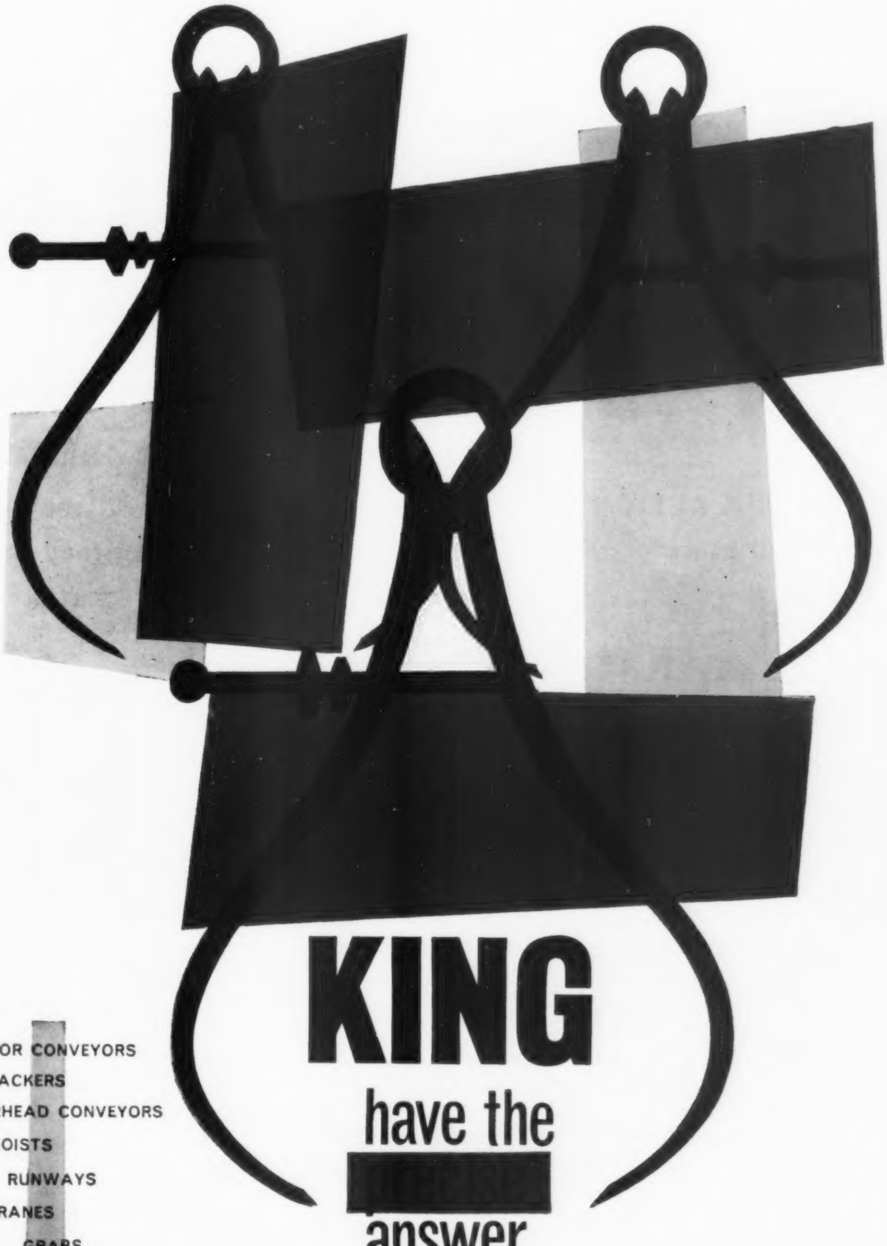

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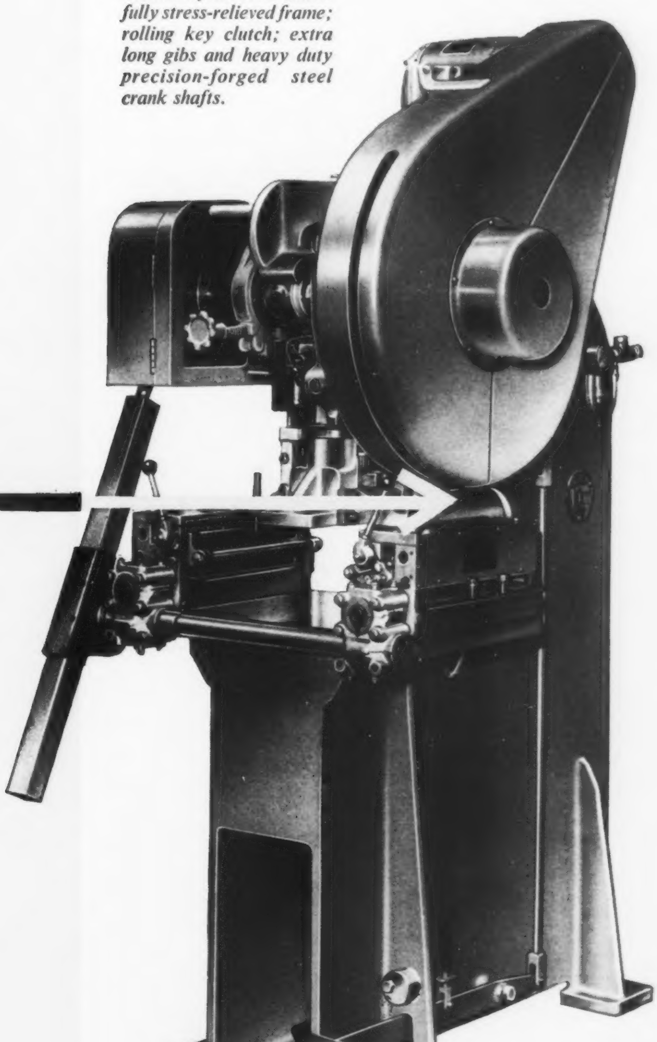

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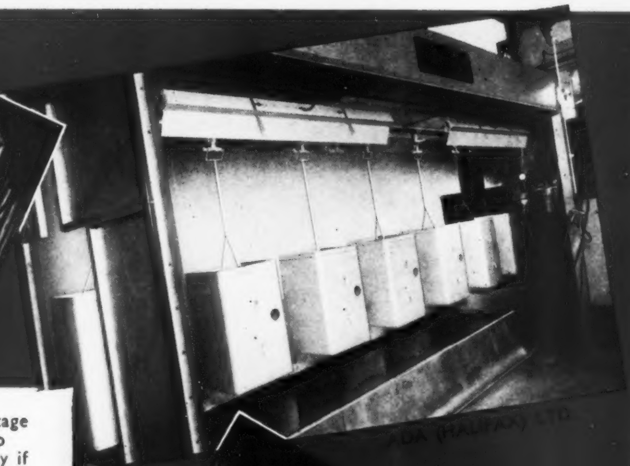

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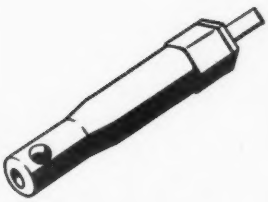

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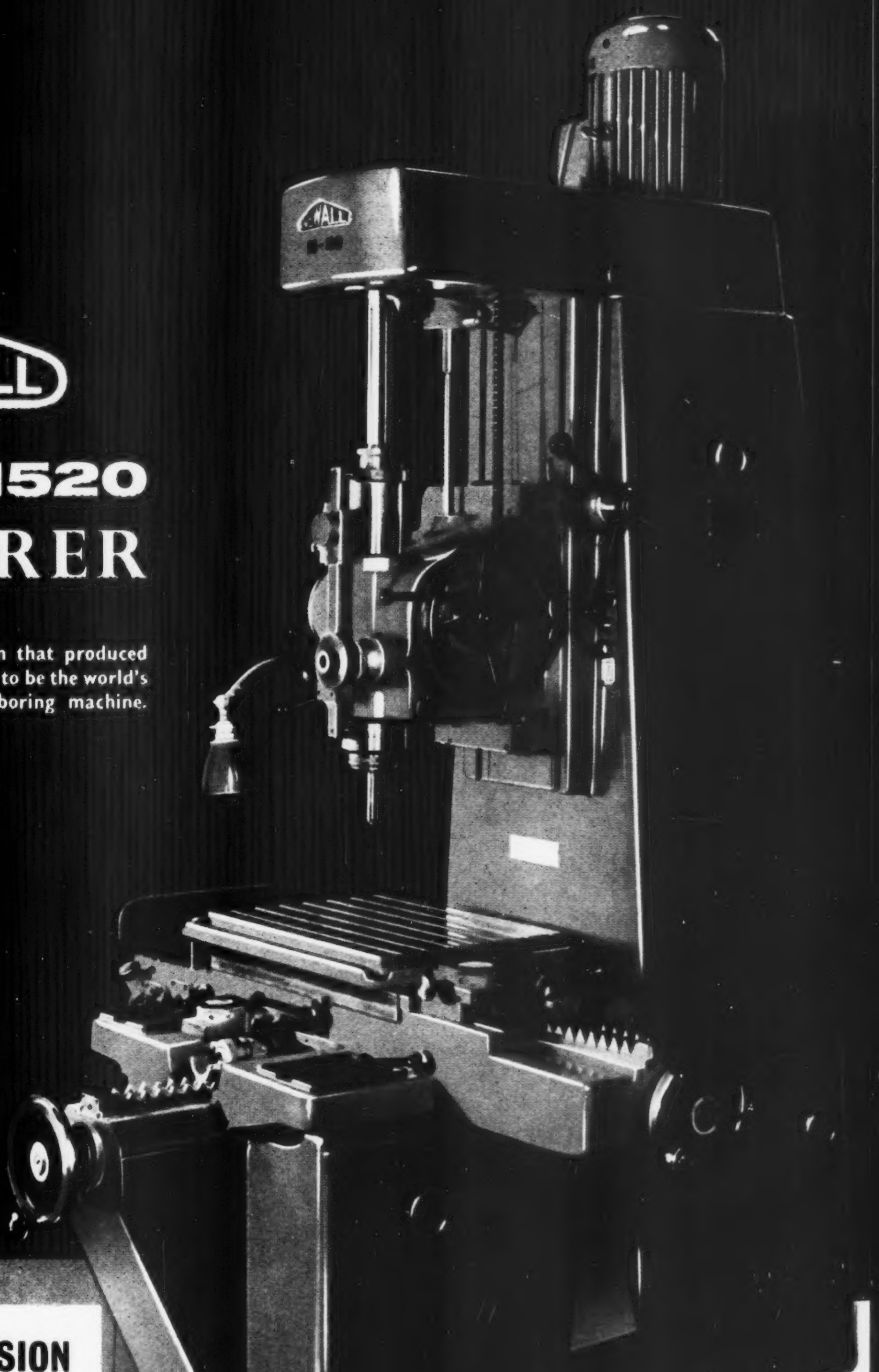

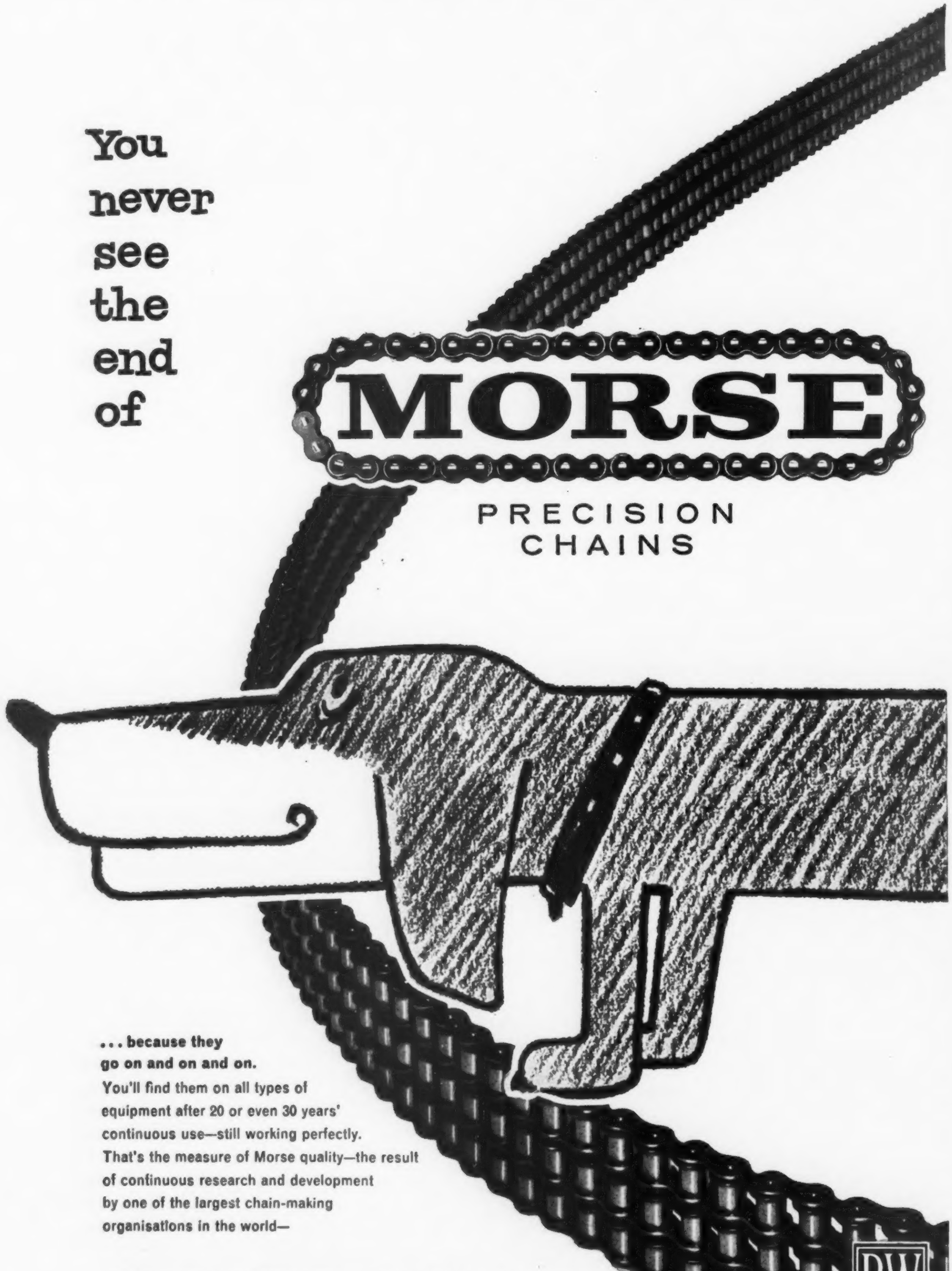
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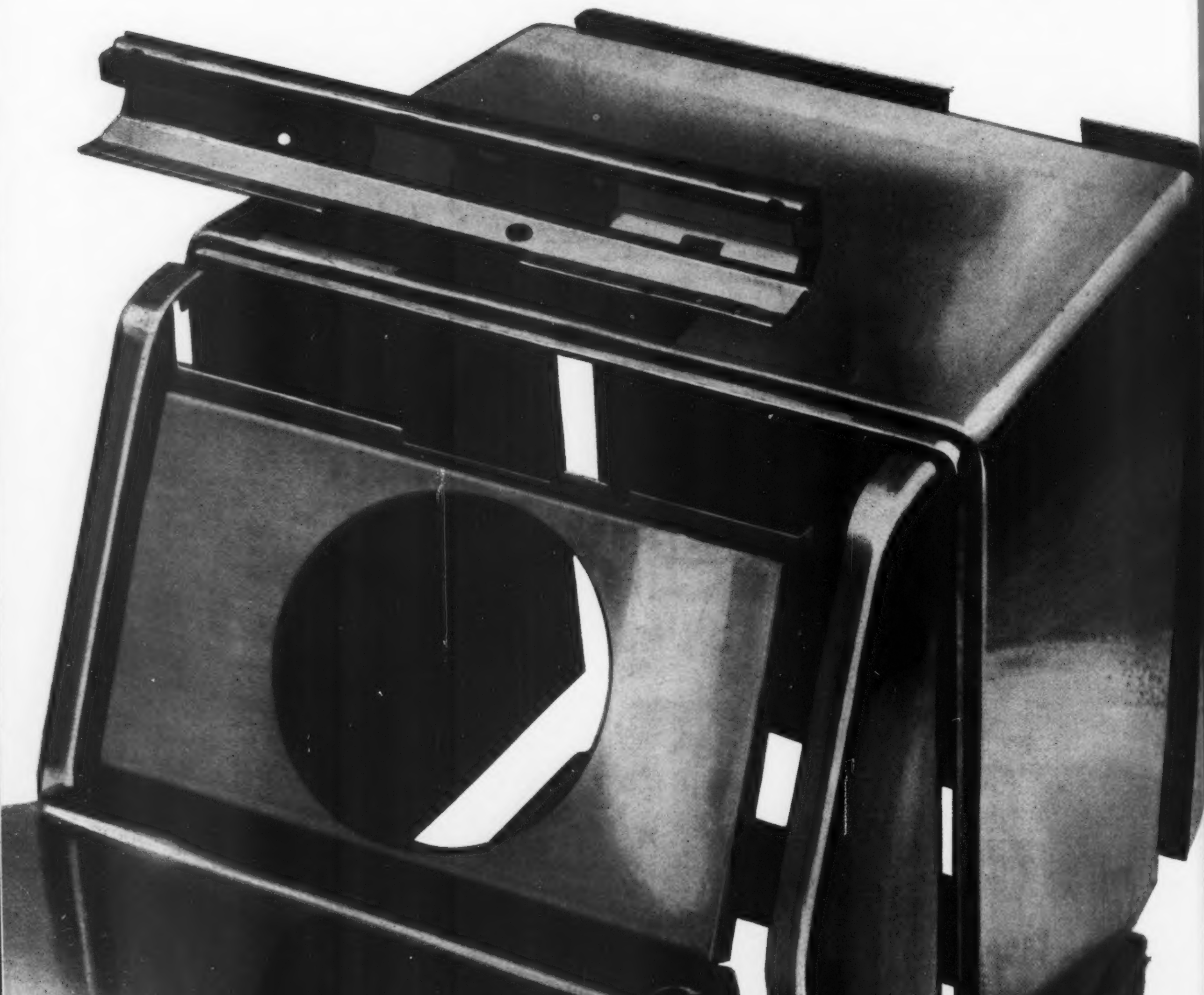

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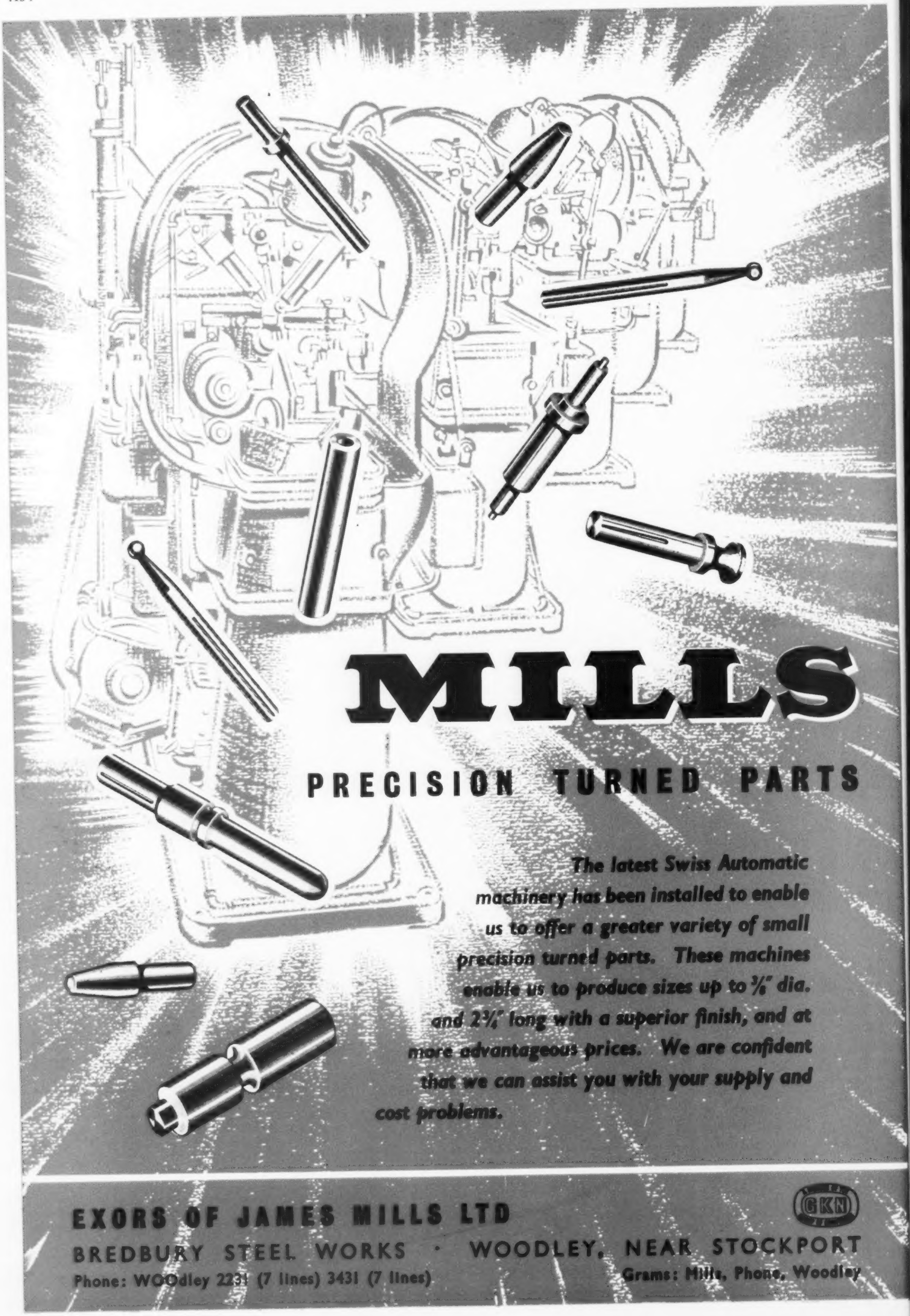
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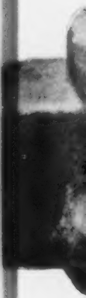

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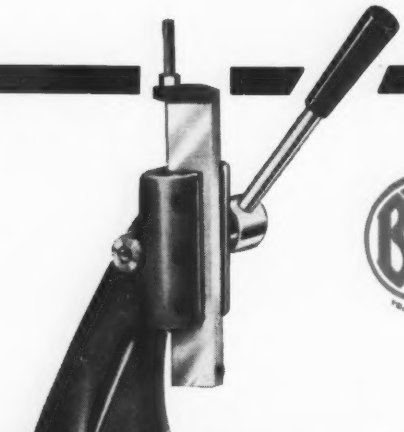

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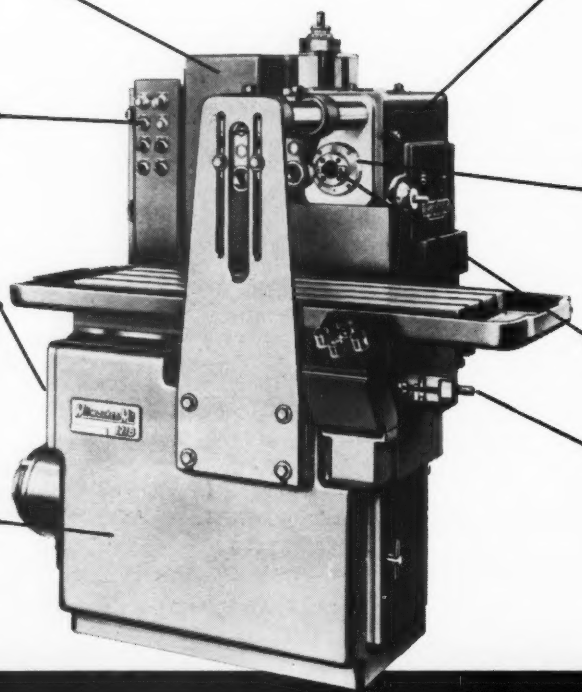

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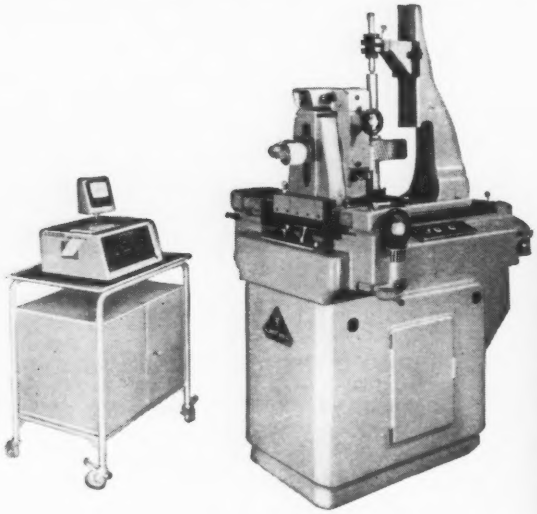

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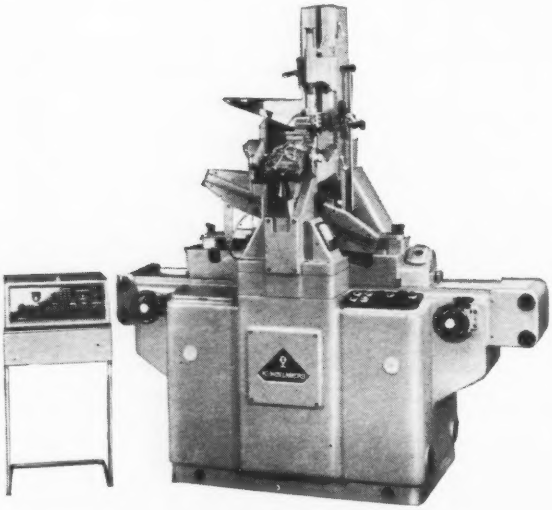

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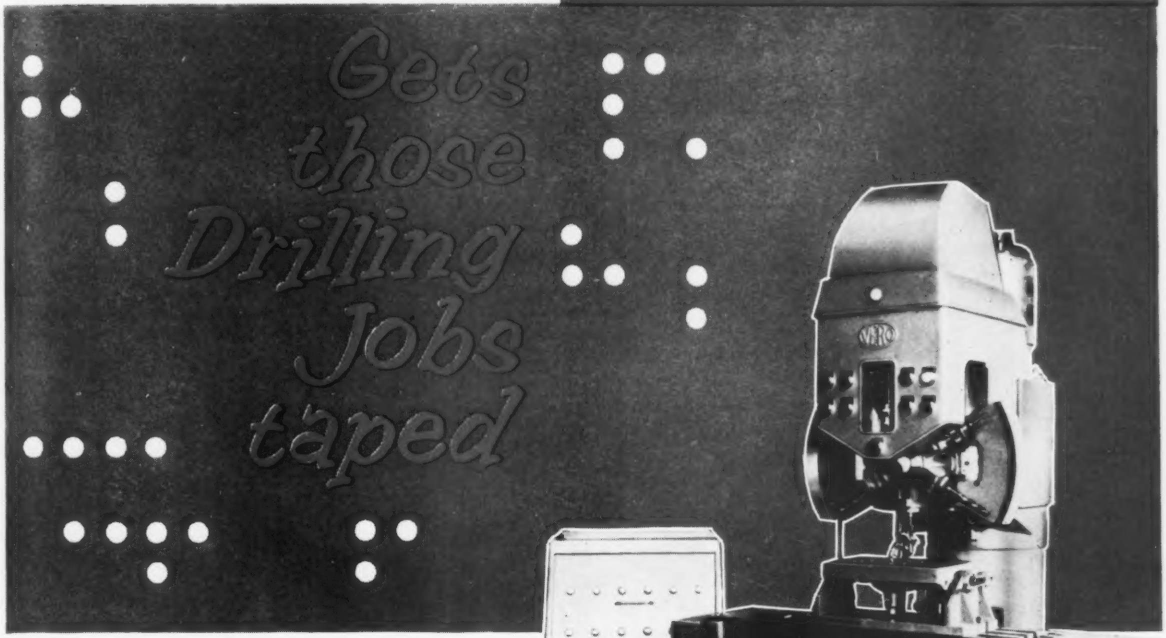

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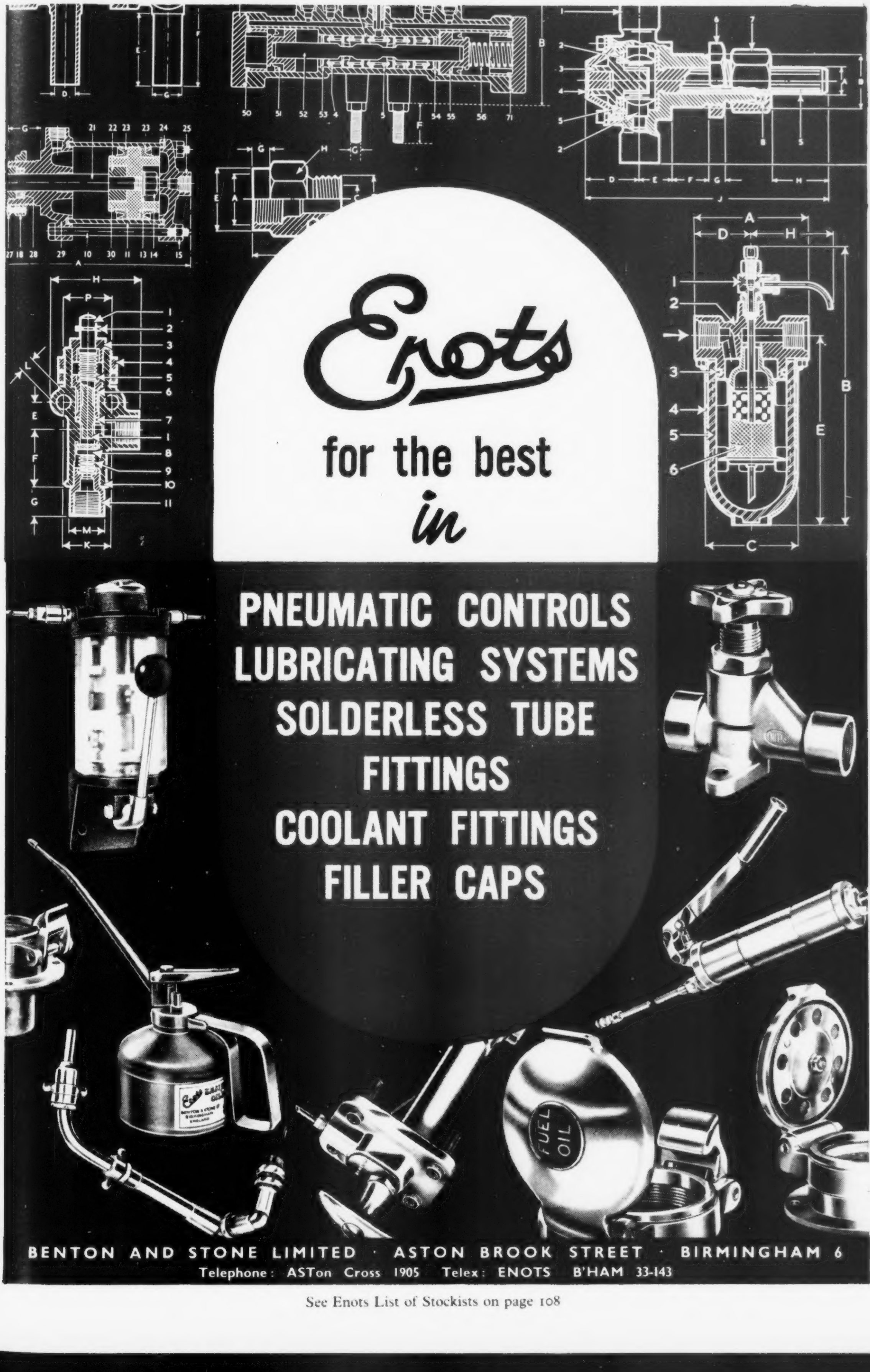

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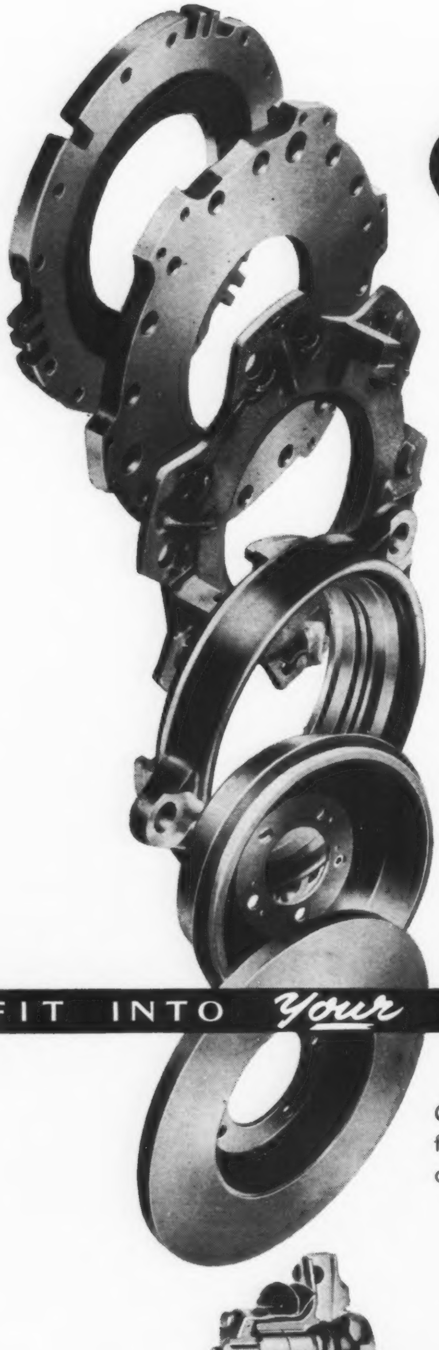
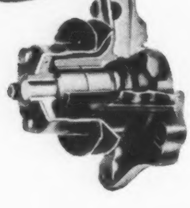




The Production Engineer

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

VOL. 40 No. 7 JULY, 1961

THE PROTECTIVE TREATMENT OF METALS AGAINST CORROSION

by H. SILMAN, B.Sc., F.R.I.C., F.I.M., M.I.Chem.E.

Past President,
Institute of Metal Finishing;
Director,
Electro-Chemical Engineering Co. Ltd.

Mr. Silman graduated in chemistry at The University of London. In 1937 he was appointed Chief Chemist of Wilmot-Breeden Ltd., and in 1940, Chief Chemist of Joseph Lucas Ltd. In 1952 he became Research Manager of the newly-established Ford Engineering Research Centre, Birmingham. He joined the Board of his present Company in 1956.

Mr. Silman's main interest has been in the field of electrodeposition and metal finishing; he has contributed extensively to the technical literature on these subjects. He has been closely associated with the work of The Institute of Metal Finishing, of which he was President during 1951 - 1953, and serves on several Government and other advisory committees.

This Paper was presented to The Institution of Production Engineers in London, on 26th April, 1961, as the 1960 George Bray Memorial Lecture.

ONE of the most striking features of modern engineering practice is the constant emphasis on lightness and weight reduction. This trend is made all the more noticeable by the fact that until comparatively recent years, solidity was one of the hallmarks of quality, and even now there is something of a tendency to regard lightweight products with suspicion. The motor industry is an instance where weight reduction has led to economies in construction and cheaper running costs, and this also applies to other applications of metals in transport. Reduction in weight is not always easy to achieve since, as often as not, it involves a careful study of the physical properties of the metals being used and also of the strains and stresses to which they are subjected.

One of the outcomes of this trend is that there is a smaller margin of safety if metallic corrosion should take place, and for this reason a great deal of attention is now given to protective treatments for metals in engineering applications. To take a typical example, the relatively thin sheet metal used for the floors of modern motor-cars has to be protected much more adequately against rusting than where a heavy steel chassis is used, as was formerly the case.

In fact, as many of the metals employed in the manufacture of consumer goods today could not perform their tasks without some form of protection,

or if they did, they would become singularly unattractive in appearance, it can be seen that the importance of correct protective treatment cannot be over-emphasised. Of these treatments, electro-plated coatings of various kinds, and also chemical conversion processes, are especially important, and this Paper will deal primarily with them. It is a field where progress has been particularly great of late not only from the point of view of the processes used, but also in the plant developed for their application. Of course, paint and enamel finishes are also very widely employed, but where mechanically operating parts are concerned, their use is generally not practicable, and in a large number of cases there is no real alternative to electro-deposited coatings.

The electro-plating of metals is now carried out on a very large scale, and the trend is to employ automatic machinery, both for the protection of individual components and also, to an increasing extent, for the manufacture of pre-treated metal sheet and strip from which products can subsequently be fabricated. The electro-plating process is basically a simple one in that the article to be plated is placed in a bath and connected to the negative pole of a source of low voltage direct current, from a rectifier: the anode or positive electrode is generally made of the metal to be plated, although in some cases an inert anode is used, the metal being supplied by the electrolyte.

The composition of the solution used plays a profound part in the nature of the deposit produced. In recent years a great deal of research has been done on the mechanism of the plating process and the effect of specific addition agents on plating solutions. The result is that not only have plating rates become much faster, but the properties of the deposits themselves can be varied widely by modifications to the solutions employed. The complete sequence of operations used in plating is an extremely elaborate one, since careful cleaning is necessary, and this in itself can involve a good many separate processes.

The after-treatments, including rinsing and drying, must also be carried out with considerable care. Apart from the thickness of plating itself, design considerations play a great part in obtaining a satisfactory product, since the distribution of metal during the plating process is far from uniform, deposits tending to be thick on protuberances and sharp corners and thin in recesses and deep crevices, and good, uniform plating cannot easily be obtained where excessive variations of form occur. It is also important to avoid blind holes and seams which can trap the liquids used in the pre-cleaning operations, and cause trouble afterwards; likewise, provision must be made for the drainage of tubular and similar components. A small point sometimes overlooked is the fact that articles have to be suspended or racked for the plating operation to be carried out, and it is as well to bear in mind that their design should be such as to enable this to be done readily. It is in these respects that the designer can play a part in ensuring that the finished product is satisfactory for its purpose.

Electro-plating as a process originated well over a century ago, with the deposition of gold and later silver for the purpose of decoration, and to enable base metals to simulate precious ones. Nowadays, however, the emphasis is more on protection and although gold and silver plating are still carried out to a considerable extent, other metals which have become of much greater importance are zinc, cadmium, nickel, chromium, copper and tin.

cleaning and pickling

As an essential preliminary to successful electroplating, metal surfaces must be very carefully cleaned, as imperfect cleaning can lead to poor adhesion and visual defects in the deposit; the cleaning sequence must be properly selected to ensure that a chemically clean surface is obtained.

The cleaning process has to remove both organic and inorganic contaminants. The first group can be sub-divided largely into mineral oils and greases and those of an animal or vegetable nature. The inorganic contaminants are largely composed of corrosion products and such substances as metallic oxides, swarf particles, and abrasive residues.

In many metal-forming and fabricating processes, lubricants are used which contain a large variety of constituents. Mineral, vegetable and animal oils and fats may be present and perhaps greases, which contain calcium and sodium salts or fillers, such as zinc oxide, which are often included in drawing compounds. The animal and vegetable oils are not soluble in water, but dissolve readily in many organic solvents and particularly in chlorinated hydrocarbons. To some extent these oils are also saponifiable by alkalis. Soaps and magnesium soaps are not soluble to any extent in water, and may be precipitated on to the metal surface from the soluble soaps when hard water containing calcium and magnesium salts is used. Many cutting oils are based on oils which are sulphurised, and the sulphur makes such oils more difficult to remove.

Other organic contaminants which may have to be removed are residues left from pickling or cleaning operations and can include such materials as strongly adsorbed pickling inhibitors and metallic soaps formed during the cleaning cycle.

Oxide residues and scale resulting from heat treatment are insoluble in water and alkalis but are attacked by acid solutions, and their removal in the main comes under the heading of a pickling operation. This is carried out in an acid, usually hydrochloric acid or sulphuric acid. Some oxides are also dissolved by cyanides, which often form part of a metal cleaning cycle for this reason where only thin films are concerned. Metal particles and other contaminants are generally removed simultaneously with grease and oil by alkaline cleaners.

organic solvents

Greases and oils are soluble in organic liquids such as trichlorethylene or paraffin, and grease removal can be effected by washing in these solvents. The ideal solvent for metal cleaning should be (a) cheap and readily available; (b) non-inflammable; (c) an effective solvent for all types of oils, greases, waxes,

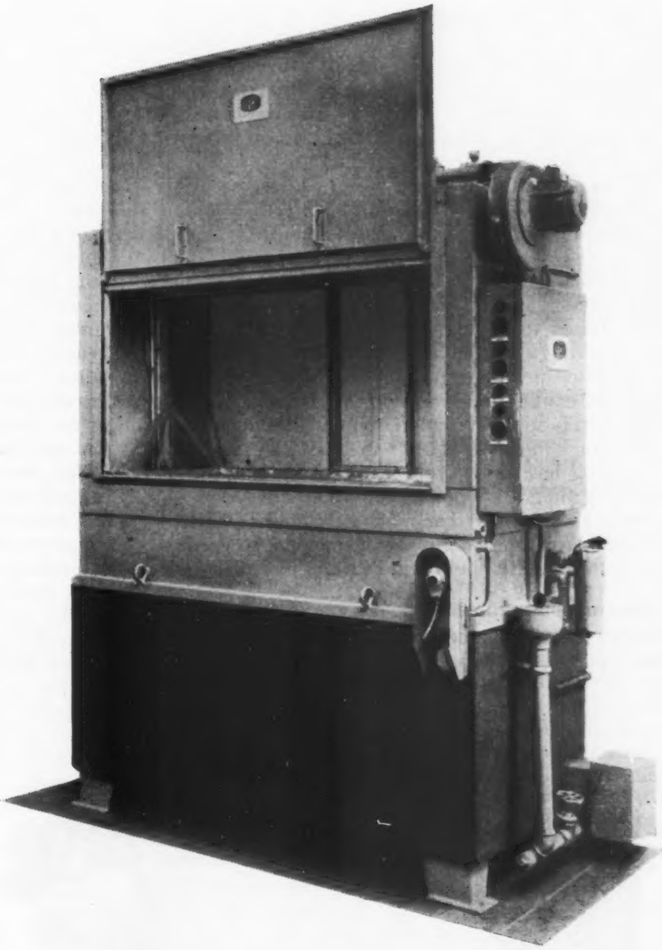


Fig. 1. Automatic vapour degreasing plant, with door open ready for loading.

(Courtesy: Electro-Chemical Engineering Co. Ltd.)

Fig. 2. Automatic vapour degreasing plant in operation.

(Courtesy: Electro-Chemical Engineering Co. Ltd.)

and tars; (d) substantially non-toxic; (e) of low viscosity and surface tension to facilitate effective penetration of greasy deposits; (g) non-corrosive to metals even at elevated temperatures. It is difficult to meet all these requirements, but they are most nearly approached by the chlorinated hydrocarbon solvents, such as trichlorethylene and perchlorethylene.

The most commonly used solvent for degreasing is trichlorethylene which is extremely effective, and is non-inflammable. It is a clear, colourless liquid, boiling at 87°C. The low specific heat and latent heat of volatilisation make it especially useful in hot solvent and vapour degreasing plants, since it is readily raised to boiling point with a small input of heat. Having a low surface tension it also penetrates readily into crevices, and as it is not affected by water, the contaminated solvent can be recovered by steam distillation. Trichlorethylene decomposes at temperatures in excess of 120° to 130°C, so that local overheating has to be avoided, whichever the means of heating that is adopted. Chlorinated solvents for degreasing purposes contains a stabiliser which greatly reduces the liability for the solvent to decompose by the action of light and heat.

degreasing plant

Degreasing plants are of three main types: (a) vapour plants, (b) liquor plants, and (c) multiliquor plants, and are usually constructed of galvanised iron or stainless steel.

The original type of vapour degreasing plant, which is still widely used, consists of an open tank in the bottom of which the solvent is boiled. Near the top, around the walls of the tank, is a bank of copper condensing coils through which cold water circulates to prevent the vapour level from rising too high. Such plants must be in a location free from draughts to lessen the amount of vapour carried into the atmosphere. Metal parts to be degreased are immersed into the solvent vapour in baskets or suspended from hooks when it condenses on to them, dissolving the grease and running off into the sump until the metal reaches the temperature of the vapour, when no further condensation can take place. As only pure condensate reaches the surface being cleaned there is no possibility of contaminated residues being left on the metal. In the case of the liquor type of plant there are two or more compartments, each containing boiling solvent. The articles to be cleaned are immersed successively in the various sections, the cleanest solvent being in the last compartment.

Modern degreasing plants are operated automatically, thus eliminating substantially the health hazard of the solvent vapour, and making them cheaper to use. A typical vapour plant is illustrated in Fig. 1, and a similar plant is shown in operation in Fig. 2;

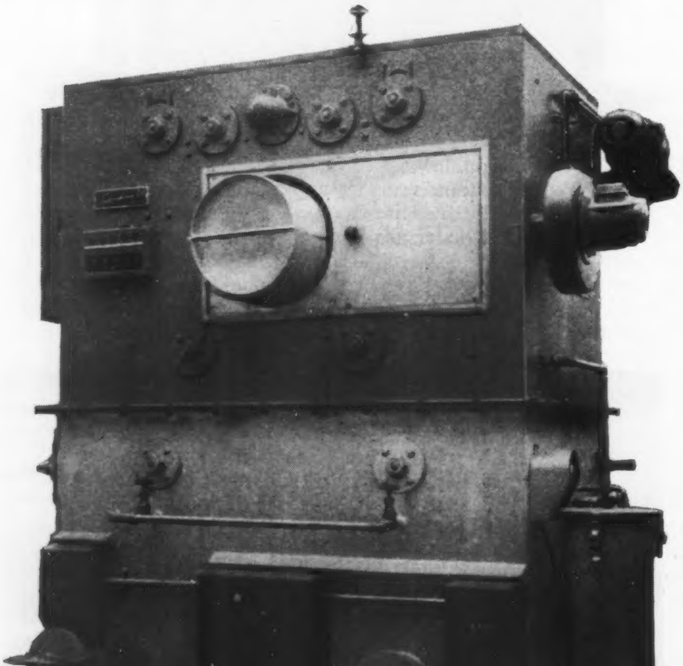


Fig. 3. Automatic vapour-liquor barrel degreasing plant for small parts. The barrel is shown in position ready for loading.

(Courtesy: Electro-Chemical Engineering Co. Ltd.)

here the work is put on to a platform, is automatically lowered into the solvent when the doors of the plant are closed, and lifted out ready for removal only when the degreasing cycle has been completed. A fully automatic plant in which the work is transferred through vapour and liquor stages is shown in Fig. 3. This plant is designed to handle small components in rotating barrels, which eliminates the problem of the cupping of solvents when hollow articles are removed from the plant after treatment. Ultrasonics are also beginning to find their place in the cleaning of parts prior to plating, and ultrasonic transducers have been incorporated in automatic solvent degreasing plants.

alkaline cleaners

Alkaline cleaning is the oldest and most commonly used process for removing surface contamination, or, following on solvent degreasing, for producing a chemically clean surface suitable for subsequent plating. The different alkalis which are employed have various functions; as a rule, a combination of several alkalis is used in the formulation of a cleaner. This must take cognisance of the nature of the metal to be cleaned to ensure that it is not attacked. In addition, small quantities of wetting agents may also be present to aid the cleaning action.

The simplest way of using an alkali cleaner is to immerse the articles in the hot solution contained in a steel tank for a few minutes. The solution is kept as near to the boiling point as possible, the agitation thus produced serving to bring fresh solution to the metal surface constantly. Grease which is removed rises to the surface of the bath and care must be taken to see that the articles are not recontaminated as they are removed. This is achieved by either skimming the surface periodically or overflowing the surface solution over a weir either continuously or periodically.

Spray cleaning is another method which is useful, the mechanical impingement of the sprays helping the cleaning operation. A filter in the cycle is advisable to prevent clogging of the spray jets. Foaming is possible in some alkaline cleaners either as the result of the inclusion of unsuitable wetting agents, or due to the formation of soaps during operation, and cleaners used in spray plants must be formulated to avoid this.

The mechanism of the removal of grease by alkaline media is complex and a variety of chemical and physico-chemical reactions come into play. Fats may be partially saponified, whilst mineral oils are removed largely by emulsification. Alkalis also deflocculate the grease, i.e., they disintegrate the contaminant prior to its emulsification and suspension in the aqueous phase.

electrolytic cleaning

Electrolytic alkaline cleaning is extensively used for the treatment of metals prior to electroplating, the articles being suspended in the solution and made cathodic or alternatively, anodic, stainless steel plates constituting the other electrode. A potential of 6 to 12 volts is used, the current ranging from 30 to 100 amps per square foot of surface being cleaned; the gas is liberated by the current at the metal surface and this disintegrates any surface film. The work is usually made cathodic, since twice as much gas is evolved here as at the anode, and consequently a speedier cleaning action is obtained. On the other hand, cathodic cleaning has the disadvantage that should any metals become dissolved in the solution, these will be re-deposited on the work by electrolysis; this can be avoided by making the articles anodic momentarily just before they are removed from the tank. The solutions used do not differ substantially from those employed in non-electrolytic cleaning, although higher concentrations of the alkali may be used to obtain good electrical conductivity.

emulsion cleaners

As their name implies, these cleaners consist of emulsions of some solvent, such as a petroleum solvent or a chlorinated hydrocarbon, for example, emulsified in water in medium to low concentrations. They are used at temperatures of 120° to 180°F, and are especially useful for the cleaning of sensitive metals, such as zinc or an aluminium which are attacked by some alkalis. They also find application in the cleaning of steel prior to phosphate treatment. In the case of the di-phase cleaners an unstable emulsion is used, the upper layer consisting of pure solvent and the lower layer of emulsion, the mixture being circulated by means of a pump and applied by spray. The take-off point is at the top of the reserve tank. The aqueous phase serves to wet the insoluble contaminants and to carry them away, whilst the solvent deals with organic materials. It is essential to use an alkali cleaner after emulsion cleaning where subsequent electro-plating has to be carried out, to avoid the carry-over of solvent into the plating tank.

nickel-chromium plate

It is not easy to realise that chromium plating, so universally employed, is a comparatively recent development, and only came into general use in the 1930's. Its versatility is such that so far as articles like motorcar and bathroom fittings are concerned, there is no really adequate substitute for this finish. Chromium deposits are almost invariably applied over a nickel undercoat on articles which are generally made of brass, steel, or zinc alloys. Chromium plated zinc-base alloy die-castings are extensively used for such parts as car door handles and motifs; the possibility of using them at all under severe conditions of exposure, either indoors or outdoors, is dependent on the fact that they can be plated with a protective deposit of nickel and chromium.

Brass castings are widely employed for bathroom and kitchen fittings, and are also generally nickel and chromium plated.

The nickel deposit is extremely important, being much heavier than the chromium, which is normally only about 0.00001 in. thick, the nickel, on the other hand, being 0.0005 to 0.0010 in. in thickness. Almost one-sixth of the world's production of nickel, i.e., some 30,000 tons per annum, is used in electroplating, the bulk of it being applied as an undercoat for chromium. The fact that this formidable quantity of nickel is electro-deposited on a wide range of

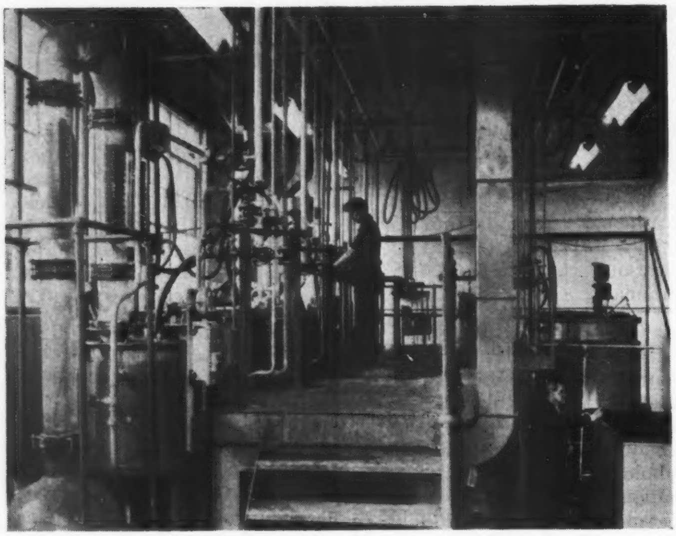


Fig. 4. Plant for manufacture of organic brighteners for plating processes.

(Courtesy: Electro-Chemical Engineering Co. Ltd.)

everyday products is a measure of the importance of the industry.

Steel is used as the base metal for such articles as car bumpers and other accessories, electric light fittings and a wide variety of decorative parts, and may or may not be thinly copper plated before nickel and chromium. The copper undercoat contributes little to the protective value of the plate unless it is a heavy one. In the latter case it is polished before the nickel is applied, since it is easier to produce a good finish on copper than it is on steel, so that the amount of polishing which needs to be carried out on the latter metal can be reduced by applying a copper deposit in the first instance. Brass and zinc-base alloy die-castings are more easily polished.

Polishing of the base metal is a necessary preliminary to almost all decorative nickel-chromium plating and is nowadays often carried out on fully automatic machines which present different facets of the articles to a series of rotating fabric polishing buffs.[1] Suitable abrasive compositions are used in conjunction with the polishing buffs and these can be sprayed on to them in the form of a liquid suspension.[2] Solid bar abrasive compositions are almost invariably employed in conjunction with hand-operated buffing wheels and still, in many cases, with automatic polishing machines. Several successive polishing operations may have to be carried out, using progressively finer abrasives until the required finish is obtained. Fig. 5 shows a typical automatic polishing machine designed for the polishing of zinc-base alloy die-cast automobile tail lamps. There is a single loading point, the lamp bodies passing around the machine to return to the same position, where they are removed.

Nickel-chromium plate is highly durable under most indoor conditions of service, but when it is exposed

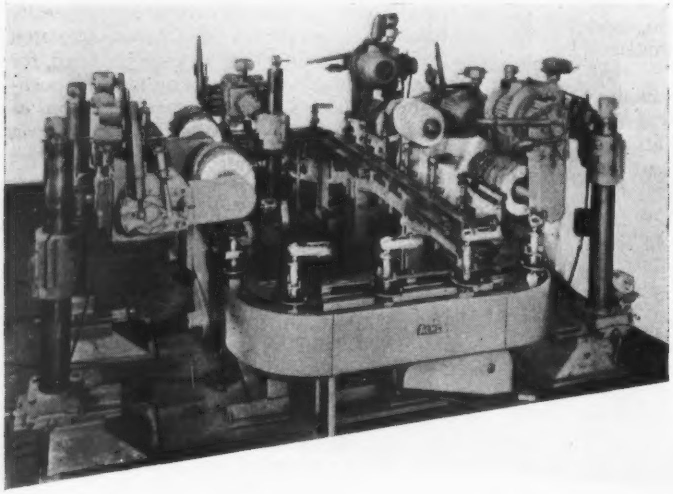


Fig. 5. A 44 ft. perimeter open centre automatic polishing machine set up for the buffing of automobile tail light castings.

(Courtesy: Acme-Efco Ltd.)

to the weather a satisfactory degree of weather resistance can only be obtained if rigid standards are maintained. This is especially the case on steel and zinc-base die-castings which are intrinsically very susceptible to corrosion. A great deal of research has gone into the development of methods of obtaining a high standard of corrosion-resistance under severe conditions of service and into methods of testing to ensure good performance.

Of all the plated coatings in current use, there is no doubt that the behaviour of nickel-chromium deposits has been the most subject to criticism, particularly on automobile parts. Since the most important single factor in obtaining a satisfactorily durable finish is the thickness of the nickel layer, a certain amount of trouble could be ascribed to a world shortage of nickel which prevailed until comparatively recent years. Nevertheless, it has been evident that there was some scope for improvement in the weather resistance of commercial chromium plating, and a great deal of effort has gone into endeavouring to achieve this. During the past two or three years much new knowledge has been gained as to how chromium plating corrodes in service, and this has changed a great many preconceived ideas. The results of these findings are slowly making their impact on the industry and methods of obtaining more lasting chromium plate are now available; the significance of these developments will be discussed in the present Paper.

the nickel layer

One of the most important changes which has taken place in the field of nickel-chromium plating in the post-war years has been the almost universal adoption of bright nickel deposits. Bright plating is achieved by the addition of small amounts of complex organic addition agents to the nickel sulphate plating solutions, resulting in the formation of brilliant nickel deposits which do not require buffing before the final bright chromium layer is applied, as do deposits from the ordinary nickel sulphate bath. Fig. 4 shows a plant for the manufacture of organic brighteners for plating processes. Many hundreds of such additives have been patented, but only a handful have met the stringent requirements of large-scale plating operation.

The obvious advantages of this procedure are that the cost of polishing the nickel plate is eliminated, whilst automatic plant in which articles can be copper, nickel and chromium plated without intermediate unracking can be employed. In modern baths, several addition agents are employed simultaneously, and are selected, not only to impart brightness, but also other desired properties to the deposit, notably " levelling " action.[3] This means that as the deposit builds up it is able to even out scratches or polishing marks in the base metal. By the choice of suitable substances the degree of levelling which can be achieved is remarkable.

The brightening agents, which are invariably sulphur-containing compounds, are occluded to a minute extent in the deposit and change its physical structure from a columnar one to a striated or laminar one. The structure of bright nickel makes it rather more susceptible to attack by chemical reagents than dull nickel, and this is thought to be due to the presence of the sulphur compounds. Under exposure to atmospheric conditions bright nickel may also in certain conditions be corrodible, as can be seen in Fig. 6, but the question as to whether dull nickel deposits are or are not superior to bright nickel so far as corrosion resistance is concerned is of somewhat academic interest, since it would be quite impracticable even to consider the introduction into the industry again of nickel deposits which have to be polished.

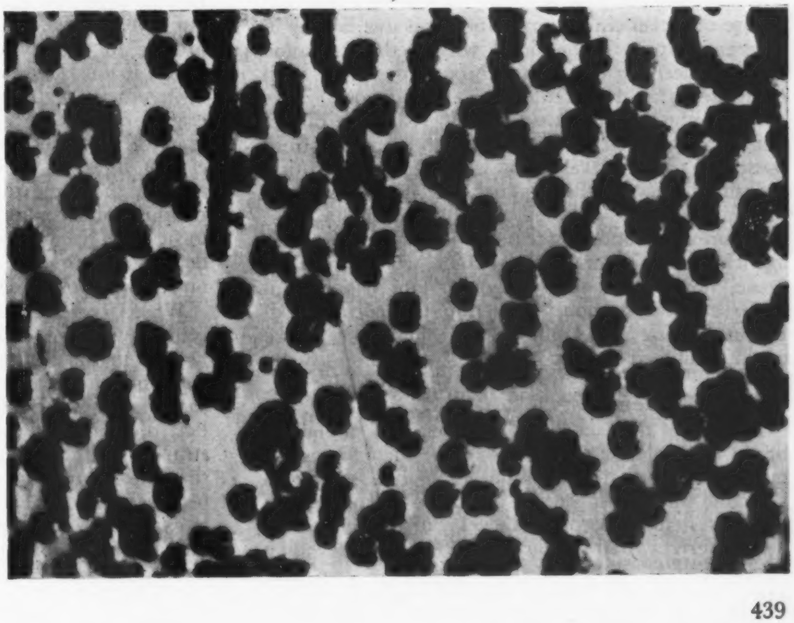


Fig. 6. Corrosion pits in a bright nickel and chromium plated steel pressing after exposure to London atmosphere.

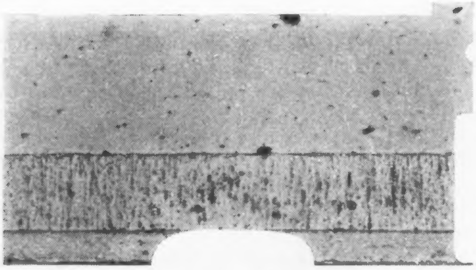


Fig. 7. Pitting in double-layer nickel/chromium-plated steel after 216 hours in acetic acid/salt spray (X 750).

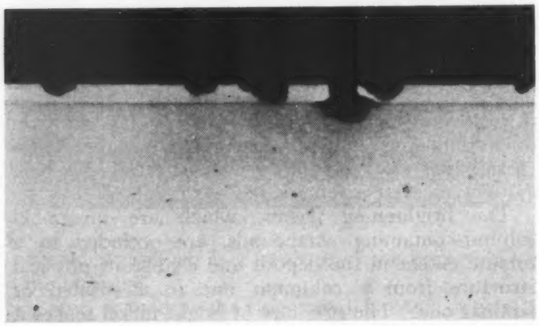


Fig. 8. Section through a pit in a corroded nickel-chromium plated specimen, showing the penetration of the nickel layer and spread of corrosion.

The thin chromium layer, which is plated on to the nickel coating from a chromic acid solution, using inert lead anodes, is now known to play a very important part in the durability of the combined deposit, and the significance of its structure and the conditions under which it is applied in relation to the corrosion-resistance of the product are only now beginning to be realised.

Until comparatively recently, it was believed that failure of nickel-chromium plating was due largely to inherent porosity in the nickel, which led to corrosion of the underlying base metal through the pores, with consequent failure of the combined deposit. The effect of the chromium was considered to be only a minor one, which served simply to impart tarnish resistance to the nickel layer. It is now realised that porosity of the nickel is of much less significance than had hitherto been believed, and that the main cause of failure is corrosion of the nickel itself by atmospheric agencies.(4) The important point which must be made, however, is that the chromium deposit can under some conditions accelerate the corrosion of the underlying nickel and hence lead to the failure of the combined deposit.

dual nickel deposits

In view of the fact that the presence of sulphur in bright nickel deposits appears to make them somewhat more susceptible to corrosion, there has been considerable interest in the use of a dual nickel deposit. In this system, a coating of nickel is first applied from a semi-bright bath, which may contain levelling agents but is free from sulphur. The deposit so obtained is smooth, but is not fully bright, as no sulphur-free compounds capable of producing fully bright deposits when added to nickel solutions are known. The work is then transferred directly to another bright bath from which the final brilliant nickel is plated. The latter only constitutes some 25% of the total deposit, which must still be kept to full specification if satisfactory results are to be obtained. It has been found in this way that the advantages of bright nickel plating can be obtained with an improved degree of corrosion resistance due to the presence of the underlying sulphur-free semi-bright deposit.

This system of plating is being used fairly extensively in the U.S.A. on such articles as bumpers and zinc-base alloy die-castings, and also in the U.K. There is some divergence of opinion as to the extent of the improvement obtained by this technique which is more marked in certain atmospheres than in others, and shows up particularly well in accelerated corrosion tests. It is found on sectioning corrosion pits which have developed in dual nickel deposits of this kind that the rate of penetration is delayed, and that when it does occur the corrosion tends to spread laterally at the interface between the two nickel layers. Hence attack through to the base metal is considerably reduced.(5) Fig. 7 shows a section through a corrosion pit in a double-layer nickel and chromium plated steel plate after exposure to an acetic acid modified salt spray test for 216 hours; the fact that corrosion does not penetrate into the second layer is readily seen.

the chromium layer

The crystal structure of electro-deposited chromium is exceedingly fine, and cannot in fact be revealed by etching or seen under a microscope. It does, however, exhibit a cracked structure which does not appear to be related to any defined crystalline form. Electro-deposited chromium is highly resistant to the atmosphere and to most chemicals, but if it is to protect an underlying metal completely against corrosion it must be applied in considerable thicknesses, owing to its high porosity and tendency to develop cracks during the deposition process. In actual practice, it is not feasible to produce deposits sufficiently thick to provide complete protection which will, at the same time, be fully bright, and as the polishing of chromium is not readily carried out owing to its great hardness, the normal procedure is to deposit a thickness of only little more than 0.00001 in. on to the nickel undercoat.

When corrosion of electro-deposited chromium commences, the attack takes place at cracks and fissures in the deposit. There appears to be an incubation period, after which fairly rapid attack occurs showing a network effect. It has been found recently that the conditions of deposition markedly affect the structure of the chromium and its corrodibility. When the chromium corrodes, the surface of the metal becomes cathodic, and the underlying nickel, which is exposed in the pores or stress cracks of the chromium film, becomes anodic; hence very rapid localised

attack of the nickel takes place. The chromium also appears to become cathodically activated as a result of the action of electrolytes and other impurities, which results in the liberation of hydrogen beneath the surface of the deposit.

Once the nickel has been penetrated, it likewise becomes anodic to the base metal, so that lifting of the chromium and nickel layers and the anodic dissolution of the underlying basis metal, with consequent failure of the entire plated coating, takes place. Fig. 8 shows a section through a pit in a bright nickel plated surface such as is seen in Fig. 6. It will be observed that some of the pits have not yet penetrated the nickel layer, but one which has penetrated is spreading horizontally under the nickel, as the steel commences to corrode.(6)

The degree of polish of the base metal also has a definite influence on the corrosion resistance of chromium deposits, a high degree of polish leading to improved protection; electrolytic polishing is said to lead to particularly good durability. Polishing of the chromium usually has little effect, but excessive heat generation resulting from attempting to polish it can lead to reduced corrosion resistance. It is desirable, from a practical point of view, that the chromium be deposited within the bright plating range and although this does not coincide with the conditions necessary for maximum corrosion protection, a reasonable compromise can be reached.

Chromium is conventionally plated from a solution of chromic acid containing about 1% of a catalyst, usually sulphuric acid, at about 100°F. The ratio of chromic to sulphuric acid as known as the "sulphate ratio" and can be conveniently kept at about 100 : 1 for the production of bright deposits. Recent work in which nickel and chromium plated steel was subjected to outdoor and accelerated corrosion tests showed, however, that a considerable improvement in corrosion resistance can be obtained by the operation of the bright chromium plating bath at 130°F at ratios of chromic acid to sulphate of 150 : 1 to 200 : 1, a somewhat greater thickness of chromium than normal (up to 0.00008 in.) being deposited at the same time.(7) Fig. 9 shows a section through a corrosion pit in which has developed underneath a crack in a chromium deposit 0.00007 in. thick plated under these conditions. The corrosion has not penetrated the nickel (which is 0.0009 in. thick) after three years' exposure to a severe industrial atmosphere, and neither has the coating lifted or flaked away.

Under these conditions minimum porosity and minimum stress-cracking were obtained, as determined by exposing chromium plated brass panels to nitric acid vapour, which serves to show up the crack pattern. The main drawback to depositing chromium in this way is that the plating current required is rather greater owing to the need to work at twice or three times the conventional current density. There is also some tendency for the deposit to be rather more blue in colour, but this can be circumvented by allowing the work to enter the plating tank whilst at a lower voltage (2 to 3 volts) before applying the full plating voltage, or by working at a lower temperature of around 120°F.

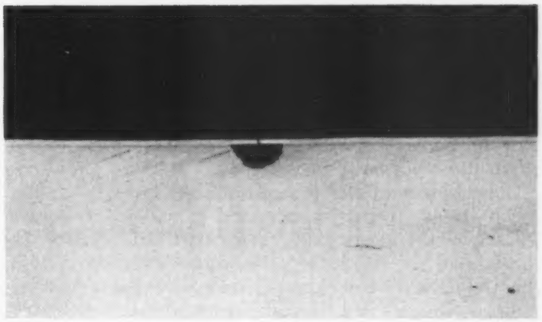


Fig. 9. Section through a corrosion pit in a bright nickel deposit under a crack in a chromium layer .00007 in. thick.

The location and nature of the cracks or pores in the chromium are important in determining the protective value of a chromium deposit, a large number of fine pores being less harmful than a smaller number of more widely dispersed large ones. This is because the relative sizes of the anodic and cathodic areas are more nearly equal in the former case, so that the rate of corrosion pitting is correspondingly reduced. Hence a fine stress pattern in the chromium deposit is less damaging to the durability of the plate than a smaller number of pores, which have the effect of emphasising the attack on the localised anodic areas beneath.

Deposits of more than around 0.00008 in. in thickness cannot be applied in this way without the initiation of cracks visible to the naked eye, particularly at high current density areas. This is a disadvantage, since owing to the poor "throw" of chromium it is sometimes necessary to exceed this thickness at such areas on articles of complex shape in order to secure an adequate deposit in recesses. A method of overcoming this problem, known as duplex chromium plating, has been developed and is now finding practical application.

duplex chromium

In this system a bright, crack-free chromium plate is deposited as described above, followed by an equal thickness of a bright, finely cracked chromium plate, the total deposit being not less than 0.00003 in.(8) Thicknesses up to 0.00010 can be employed with safety, and in fact this may have to be plated on high current density areas in order to obtain the necessary thickness in recessed zones owing to the poor distribution of chromium deposits. This makes the process particularly suitable for zinc-base alloy die-castings, which are often of very involved design. The first crack-free chromium may be obtained by plating from a solution of chromic acid and sulphuric acid, the chromic acid concentration being between 250 to 400 g/l. The ratio of chromic acid to sulphate is between 125 and 175 to 1, the temperature of operation being 120° to 130°F.

After plating this deposit, the cracked chromium layer is applied from a dilute bath containing about 200 g/l of chromic acid at 115° to 125°F immediately after the first chromium bath, the articles entering the

solution bath at a low voltage to prevent streakiness. Fluoboric or fluosilicic acid catalysts in the bath, in addition to sulphuric acid, are helpful in producing the required fine stress-cracking. This second chromium deposit also tends to cause the underlying chromium layer to crack, so that finer cracks occur than those normally present.

The object of the first chromium layer is, as has been stated, primarily intended to provide coverage of the nickel, particularly in recessed areas, since the bath used for producing the second cracked deposit has relatively poor "throw" and would not give an adequately uniform deposit if used alone.

A further advantage of the underlying crack-free deposit is that, being itself in a state of stress, it serves to promote the desired finer type of crack in the subsequent chromium layer which, being of microscopic dimensions, is not unsightly. Hence the combined deposit tends to become a finely cracked one. It is, however, essential that the fine cracking should develop properly, since a thicker chromium deposit which has numerous larger cracks or pores, can actually be worse from the corrosion point of view than the thinner chromium normally used, owing to the relatively large proportion of cathode to anode areas.

A further advantage which is claimed for the cracked duplex deposit is that it is naturally relatively stress-free, so that it has less tendency to crack or detach the underlying nickel plate than conventional chromium. Exposure tests indicate that a substantial improvement in corrosion resistance can be obtained by the use of such chromium deposits on nickel plate as compared with the normal type of chromium deposit.

It is evident, of course, that still greater improvements might be expected if the dual nickel deposit were used in conjunction with dual chromium. This combination is, however, not yet being employed to any extent because of the considerable complexity of the operations involved.

Another recent development directed towards the production of more durable plating is the use of a combined chromium-nickel-chromium or nickel-chromium-nickel-chromium deposit on steel or zinc base alloy articles.[9] An advantage of these systems is that the first chromium layer need not be plated within the somewhat narrow bright range of the chromium bath, so that plating can be carried out under conditions giving deposits of maximum corrosion-resistance; such conditions do not always coincide with those under which fully bright chromium plate is obtained.

When nickel deposits are sandwiched between chromium layers the type of corrosion which occurs differs from that of nickel-chromium deposits alone, in that it does not tend to penetrate downwards to the basis metal but proceeds much more slowly laterally within the nickel layer. Hence the durability of the combined plate is greatly increased. The system is particularly durable when applied over copper on complex-shaped zinc-base alloy die-castings where the deposits tend to be relatively thin in any case. A chromium deposit of 0.00001 in. from the usual type of chromium bath, followed by 0.0005 in. of nickel and the same thickness of chromium again, gave protection equal to that of a nickel coating of double the thickness when applied in the form of normal nickel and chromium plate.

zinc and cadmium plating

Both zinc and cadmium coatings differ from those of the more noble metals such as nickel and chromium in that their action depends less on complete coverage of the underlying steel (on to which they are generally applied), as on the fact that their protection is sacrificial. This means that at discontinuities in zinc or cadmium deposits, the coating metal is corroded away in preference to the ferrous metal, and protection is afforded in this way.

Zinc is a very much cheaper metal than cadmium, and is used extensively on fittings and components, such as switchgear, lock mechanisms, window channels and winding gear in motorcars, and the like, the deposit thickness being of the order of 0.0003 in. The thinness and uniformity of the zinc coating makes it particularly suitable for the treatment of screws, since the plating does not seriously affect thread diameters, and automatic machines have been constructed for the bulk treatment of nuts, bolts, and screws on a large scale in barrels. Electroplated deposits are very much thinner than those applied by hot dip galvanising, and are correspondingly less durable, but are nevertheless eminently suitable for their purpose. The deposit is generally applied from a cyanide solution which has a very high throwing power, so that a good coating is obtained in recesses. Cast iron or malleable iron parts are not readily plated from a cyanide solution and an acid sulphate bath is therefore preferred in such cases.

Zinc deposits are rather dull in appearance as plated, but it is possible by the use of various addition agents to obtain very bright zinc coatings which are much more attractive in appearance, and resemble chromium plating. Naturally, the zinc does not retain this brilliance indefinitely, but it can be preserved by the application of a lacquer, whilst after-treatments are also available which will make it last longer.

Cadmium is much more attractive in appearance than zinc, being whiter and more lustrous. The coating is also more ductile, so that it can be formed more readily after plating. It also has a lower coefficient of friction which is a useful feature when it is deposited on screws. Cadmium plating is most widely used on radio chassis parts, motorcar electric equipment, and on screws and nuts for many engineering accessories, notably aircraft parts. It is much easier to solder than zinc and having greater resistance to alkalis, is useful on domestic equipment, such as refrigerator shelves. Its resistance to acids is low, however, so that cadmium plating must not be allowed to come into contact with acid foodstuffs; this is particularly important because of the toxicity of its compounds. Cadmium also retains its surface conductivity longer than zinc, which makes it very useful for electrical applications. For outdoor exposure, somewhat heavier cadmium deposits are extensively employed on steel parts used in aircraft and

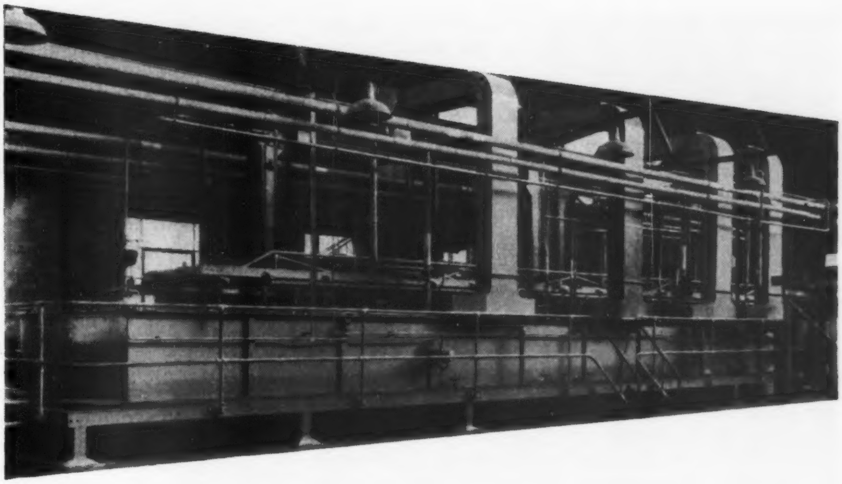


Fig. 10. Automatic bright cadmium plating plant. Note automatic load-unload mechanism on the extreme right.

(Courtesy: Electro-Chemical Enigineering Co. Ltd.)

marine equipment, because it has better resistance to salt atmospheres than zinc; this applies particularly in tropical conditions. Zinc deposits appear to be more durable, however, in industrial atmospheres. Bright cadmium plating processes are also available, which are particularly attractive in appearance and have been used extensively in electronic applications.

One of the hazards which is liable to be met with in cadmium and also in zinc plating is a phenomenon known as hydrogen embrittlement. This is caused by the adsorption of hydrogen into the steel during the plating operation as this gas is liberated at the cathode. By entering the crystal lattice of the steel, it renders the latter metal brittle, making it liable to fracture in service. This is particularly likely to occur if the steel has been subjected to any hardening treatment. Methods of relieving the effects of hydrogen embrittlement are available, the commonest being some kind of low temperature heat treatment, but these are not always entirely successful.

Fig. 10 shows a fully automatic plant which cleans, bright cadmium plates and chromate treats a wide range of steel electronic components, and also valves and couplings amongst other articles; these are suspended on standard size racks, which take about an hour to pass through the machine, 100 of such racks being processed each hour. An automatic loading unit is also provided which hydraulically lifts each plating rack from the overhead factory conveyor and transfers it to the plant, so that no operator is required for loading or unloading it.

conversion coatings

Zinc deposits, and to a lesser extent cadmium, are prone to develop white corrosion products consisting of basic salts under conditions of humidity. The corrosion products are both unsightly and likely to interfere with the operation of mechanisms which have been plated with these metals. For this reason, a good deal of attention has been devoted to after-treatments for zinc and cadmium plate, which will prevent this occurring. Many of these finishes are based on the use of solutions of chromates which are slightly acidified, and are often termed "conversion coatings", because they are formed by the conversion of part of the metal to one of its compounds. This type of treatment is also often referred to as chromate passivation. On immersion of the plate in the solution, a film is obtained which can range in colour from yellow or drab to an almost transparent appearance.

The conversion coatings are highly useful and serve to improve the life of plated parts considerably. The effectiveness of the film depends on the liberation of traces of chromium compounds in any moisture which may come into contact with the metal and so reduce the tendency for white corrosion compounds to form. The deeper coloured films are more durable than the transparent ones, although they are, naturally, correspondingly less attractive. Nowadays, practically all bright zinc and cadmium plate is treated in this way; in the case of cadmium, the light coloured chromate films do not interfere with the solderability of the coating, even after relatively prolonged storage. Chromate treatment in the case of zinc is specially useful where the metal has to be painted, since it greatly improves the adhesion of the paint film.

There are other conversion coatings in widespread use in industry, of which the most important are the phosphating processes. These are mostly applied on iron or steel by treatment in a hot solution of an acid phosphate. This converts the iron surface to an insoluble tertiary phosphate which has limited protective value itself, but is a valuable basis for further protection processes.

The phosphate coatings are produced by two main types of process. The first group is made up of the iron and manganese phosphate processes which produce a heavy coating suitable for impregnation with oils, waxes or special lacquers; this type of coating is employed on tools and fittings of various kinds where a utilitarian and inexpensive finish is required. The second group is based on the acid zinc phosphate processes; the coatings in this case are much thinner

but form excellent bases for paint and enamel finishes, improving adhesion and reducing the spread of corrosion which can occur if the organic finish is damaged.

A British Standard Specification (B.S.3189, 1959) has recently been introduced for phosphate coatings and covers five classifications, ranging from the heavy-weight manganese or iron phosphate coatings for wear resistance (greater than 700 mg/ft^2) down to the smooth extra lightweight coatings of 30 to 100 mg/ft^2 for use as undercoats for paint on items such as steel furniture, toys, etc.

Conversion coatings are also widely used on aluminium and its alloys. These coatings, of which the main groups are (a) alkaline chromate, (b) acid chromate-fluoride, and (c) zinc phosphate-fluoride, are designed to improve the paint adhesion on aluminium and its alloys, which is not normally very good. The treatments are applied from hot solutions, by immersion or spray, the time of treatment ranging from 1 to 10 minutes. The coatings are of a variety of colours, ranging from light yellowish-green to dark grey. Some of the treatments are also suitable for outdoor exposure alone, and serve both to protect the aluminium from attack by the atmosphere under adverse conditions, and to reduce its reflecting characteristics. This latter feature improves its appearance when the metal is used for building applications.

Many of the developments in conversion coatings on aluminium are relatively recent, and the performance of these finishes is excellent.

automatic plating

Until comparatively recently, it was considered that automatic plating plant was limited in its application to conditions where large quantities of components of the same, or similar, design had to be dealt with. Hence, the majority of such machines were installed in factories where mass produced articles were being plated, particularly in the automobile industry. Where the work was more varied, or was likely to change considerably in form or type of finish required, mechanised plant was considered to be unsuitable. The present much more widespread use of automatic plating methods has been brought about by a variety of factors, not the least of which is the increased versatility of the electro-plating processes themselves. For example, the earlier bright nickel solutions were relatively restricted insofar as their bright plating range was concerned, so that unless conditions were carefully controlled and the type of work put through them limited, poor results could be obtained. Where a plant was designed for bright nickel and chromium plating in a single operation, it was not easily possible to remove the work after nickel plating to carry out a buffing operation if the work was not fully bright, as could be done in hand operated lines. Modern processes will produce bright deposits under an exceedingly wide range of conditions, so that this restriction no longer applies.

Automatic plants are now being installed even in the works of jobbing platers, despite the apparent limitations imposed by the fixed tank and rack sizes and the process sequences. Whilst it is true that process cycles and times can be more readily varied in a hand-operated plant, modern cleaning and pre-treatment systems can be so designed that they will cope with almost any metal condition, and a wide variety of product sizes, designs and materials.

Automatic plating plant is not nowadays installed primarily with a view to saving labour, although this is a factor which was, at one time, considered to be the only justification for mechanisation. In fact, automatic plants are being installed in countries such as India and Japan, where labour costs are low and are, in fact, likely to be lower than capital charges.

In the U.K., plating processes, and particularly the allied polishing processes, are not attractive as far as labour is concerned, and yet to carry them out satisfactorily by manual methods demands a high degree of application and conscientiousness and hence a good type of labour. The conditions of work in a plating shop can be unpleasant, as operators have to wear protective clothing, stand on wet floors and work in humid atmospheres. For this reason, manufacturers are more and more inclined to look to mechanisation to give them consistency of production, and to use plating plants as machine tools strategically located in their appropriate positions in the production line.

The particular advantages in mechanising plating processes can be summarised as follows :

1. the elimination of the need for skilled personnel to carry out involved cleaning and plating operations;
2. the achievement of a high degree of uniformity in quality, and a reduction in the amount of substandard plating;
3. a reduction in the amount of damage caused by handling;
4. improvement in factory layout, and usually a substantial saving in floor space;
5. improved working conditions and reduced building maintenance by the elimination of the "plating shop";
6. a high percentage of plant utilisation, enabling an assured output to be maintained;
7. deeper tanks and larger racks than would be practicable with manual handling can be employed, resulting in substantial economies.

From the point of view of quality, mechanisation is almost essential in large scale production to ensure that none of the vital steps in the complex plating sequences is omitted or skimped.

problems of mechanisation

The problem in mechanising plating operations is to carry a series of articles on racks or sometimes in barrels through a number of processes successively, the time for each ranging from perhaps a minute or two up to hours. The work must be transferred through the tanks, sometimes with and sometimes without the application of current, smoothly and efficiently. As an indication of the elaborate sequence of operations which must often be carried out, a typical cycle of the requirements for the chromium

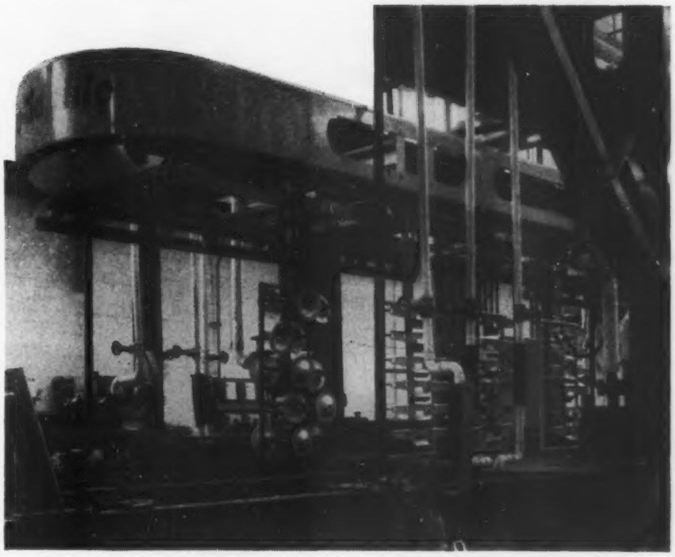


Fig. 11. Automatic plant for bright copper plating steel parts prior to nickel and chromium. The lifting frame is in the raised position.

(Courtesy: Jaguar Cars Ltd. and Electro-Chemical Engineering Co. Ltd.)

plating of steel automobile components is shown in Table I.

TABLE 1

Cycle of Operations for Plating Steel Automobile Parts.

1. Alkaline clean (cathodic)	11. Bright nickel plate
2. Warm rinse	12. Cold rinse
3. Alkaline clean (anodic)	13. Cold spray rinse
4. Cold rinse	14. Warm rinse
5. Copper plate	15. Chromium plate
6. Cold rinse	16. Recovery tank
7. Cold rinse	17. Cold rinse
8. Hydrochloric acid dip	18. Neutralising tank
9. Cold rinse	19. Cold rinse
10. Cold rinse	20. Hot rinse
	21. Hot air dryer

In most present-day plants for the plating of individual articles, information regarding the cycle which the plant is to perform is built into a controller which forms part of the electrical control system. This controls the entire sequence of operations, and ensures that each article receives the precise treatment prescribed for it.

Automatic plants are of the "straight through" or "return type". In the former, the articles are loaded and unloaded at opposite ends of the plant, but in the latter they travel around the machine and are loaded and unloaded at the same point.

The automatic plating units currently employed are mainly of the return-type, in which the tanks are arranged in a closed system so that the work returns to one position where both loading and unloading are carried out by a single operator. This also eliminates the need for sending plating racks back to the loading end of the plant, which is a problem with "straight-through" types of machines. A widely used design of automatic plant of this kind for plating work

Fig. 12. The loading and unloading station of the plant shown in Fig. 11.

Fig. 13. Automatic nickel and chromium plating plant for copper plated and brass automobile components.

(Courtesy: Jaguar Cars Ltd. and Electro-Chemical Engineering Co. Ltd.)

on racks or frames utilises a hydraulically operated carriage running the length of the machine which is alternately raised and lowered, carrying sections of the cathode track (which may be a single or double one) with it. When the carriage is in the elevated position, the racks are moved forward by pushers attached to reciprocating T-bars acting on sliding suspenders carrying the racks along the cathode track itself, thus transferring them from one tank to the next. The main plating tank, where this is a long one, can also be extended beyond the carriage, the movement within the tank being taken over by a separate mechanism. By the use of this modification the cost of the plant is reduced, since a shorter and lighter superstructure is needed.

In the longer stage processes the pushers move the racks whilst they are in the tanks, when the lifting frame is in the lowered position; hence an intermittent movement is obtained which usually takes place at approximately one minute intervals, the articles being stationary except when a transfer is being effected. At the ends of the plant segments oscillating in a horizontal plane guide the work suspenders around the machine. A ratchet mechanism prevents the racks from moving backwards as the pushers are reversed. A single-track return-type plant of this description will deliver from forty to eighty racks—equivalent to about 200 sq. ft. of work—per hour. Two-track machines deliver up to 160 racks per hour on an average but the cycle is to some extent variable and is controllable by a central selector switch box.

The raising and lowering of the counterbalanced carriage of the plant is carried out by means of chains, attached to horizontal hydraulic cylinders mounted on the lifting frame. Many hundreds of such plants, which can be up to 150 feet and more in length, are in operation through the world. Hydraulic machines have the advantage that the time cycle and the time of lift and drop can be readily varied if it is desired to alter the plating cycle.

A typical installation for the plating of steel motor-car parts[10] making use of pre-copper plating before nickel and chromium, is shown in the accompanying illustrations. Fig. 11 illustrates an automatic machine for bright copper plating miscellaneous steel components, such as boot lid fastenings, ash-trays and gear-levers, with the lifting frame in the raised position; the loading and unloading station is shown in Fig. 12. After polishing, the parts are then transferred to another automatic plant which carries out

Fig. 14. Automatic plating machines for automobile parts (left); hoist-operated line of plating tanks (right).

(Courtesy: Jaguar Cars Ltd. and Electro-Chemical Engineering Co. Ltd.)

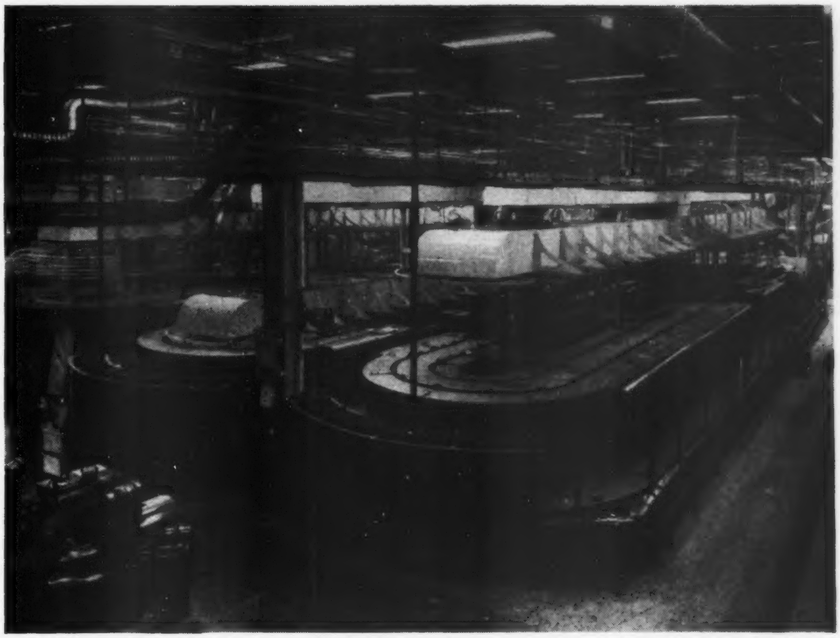


Fig. 15. Installation of return - type automatic machines for nickel and chromium plating automobile lamp components. (Courtesy: Joseph Lucas (Electrical) Ltd. and Electro-Chemical Engineering Co. Ltd.)

the bright nickel and chromium plating stages; the loading of radiator grilles on this machine is shown in Fig. 13. The two machines are shown in line on the left of Fig. 14; on the right is a line of tanks for plating larger components in which the racks are transferred from tank to tank by means of a power operated hoist.

Another large installation is illustrated in Fig. 15, which shows one of three automatic plants for the copper, bright nickel and chromium plating of automobile lamp components in a single sequence.

For the plating of small components barrels are used, the parts being rotated in them through the complete cycle of operations. The anodes are suspended in the tanks and cathode contact is made by means of an electrode in each barrel. Fig. 16 shows a small automatic barrel type of plating unit in which the barrels are lifted by a cam and roller mechanism. Much larger machines of this type have also been built.

This design of plant can also be adapted for racked work.

pre-plated metals

An important development in recent years has been the greatly increased use of the pre-plated metal, both in the form of sheet and strip for the manufacture of finished products by forming and pressing. Of the materials available, probably the most significant, apart from tin-plate, is zinc-coated steel. Other electro-plated metals currently produced are nickel plated steel and brass, copper plated steel, and to a lesser extent copper and tin plated brass. Nickel-chromium plated steel sheet is not produced, since it is not readily capable of being bent or formed without cracking of the chromium layer. Articles which are to be chromium plated are first formed from nickel plated strip and subsequently chromium plated. Another form of plated steel for a special application is narrow copper plated strip which is used for making into tubing by copper brazing; this process effectively joins the coppered surfaces together, resulting in strong continuous thin-walled steel tubing.

The advantages of using pre-plated metals are considerable. In the first place, there is usually an economic advantage, since plating costs are higher where individual components are concerned than when these are produced from plated metal. Such savings can amount to from 40% to 60%. Secondly, there is the saving of space and capital resulting from the elimination of the need for finishing plant and facilities. Pre-plated metal is also generally much more uniformly plated than is possible when finished articles are treated. This is chiefly because the anode-cathode distance is readily kept constant when flat metal surfaces are being plated. Thus zinc plated sheets up to 48 in. in width vary by not much more than $\pm$ 5% in coating thickness over their entire surface. Hence articles post-formed from plated sheet or strip are less likely to be thinly plated in recesses, particularly when they are of complex shapes, than when the finished product is plated.

Against these advantages, however, the use of pre-plated metals results in a certain necessary wastage, whilst only relatively thin deposits can be plated in the case of metals such as nickel if the strip is to form satisfactorily. Other problems such as welding and jointing also arise, and the protection of sheared edges must receive consideration.

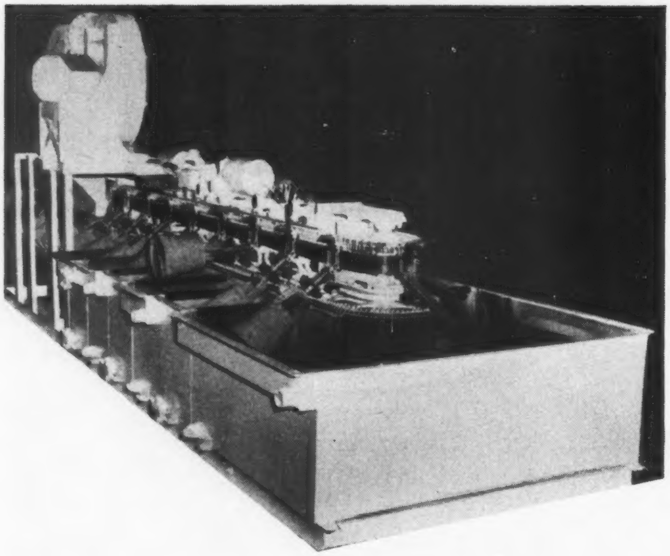


Fig. 16. Small automatic barrel-type plating machine.

(Courtesy: Frederic B. Stevens Co.)

Plated strip (other than galvanised) is produced on a relatively small scale, and in widths of not more than about 2 ft. The process consists in drawing the strip through a series of tanks where the cleaning, plating, rinsing and drying operations are carried out. The strip may be treated either horizontally or vertically and the plating speeds are usually quite low.

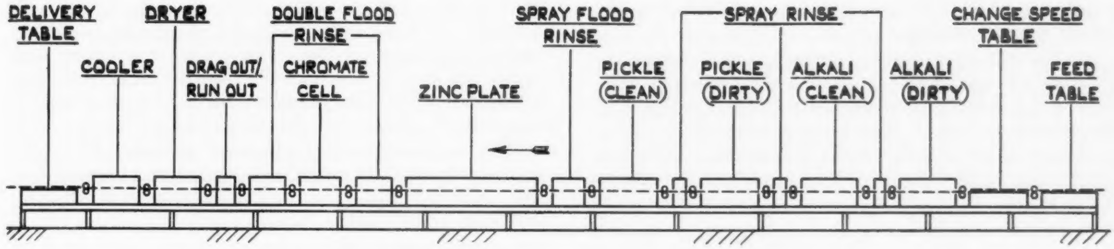
electro-galvanised steel sheet

Electro-galvanised steel sheet is nowadays an extensively used product and is produced on a large scale in fully automatic plants. It should not be confused with hot galvanised steel with which it is not competitive, having entirely different characteristics and applications. Electro-galvanised steel carries a zinc coating generally 0.0001 in. thick, which is only about one-tenth of the thickness of the hot dipped coating. However, by virtue of the method of manufacture, no brittle alloy layer exists between the steel and the zinc so that the product can be subjected to a considerable degree of deformation without damage to the coating, and can even be deep drawn without destroying it.

The material is primarily intended for use in steel products which have to be painted or enamelled, since the deposit is smooth and uniform, and when suitably treated, provides an excellent key for organic finishes. With untreated steel, local failure of the enamel film as a result of mechanical damage or for other reasons results in rapid rusting of the underlying steel, and flaking of the paint film due to the spread of corrosion products beneath it. When a thin zinc deposit is present, however, this is less liable to occur, since the deposit protects the underlying steel both mechanically and electrochemically against further attack. Some products which only require a low degree of protection where the conditions of service are mild can be fabricated from electro-galvanised steel without further finishing, but such applications are limited in number. The anodic protection afforded by the zinc coating extends for some distance; thus it is found that no progressive corrosion takes place at the cut edges of the material. Electro-galvanised steel is extensively employed for such articles as steel kitchen cabinets, refrigerators, office furniture, steel partitioning and door frames, and a wide variety of other parts. In the motor industry, the material finds application in the manufacture of petrol tanks, air-cleaners and silencers, and parts subjected to severe conditions of erosion such as under-bodies and the air-intake manifolds of car heating equipment. Differential coatings, thicker on one side than the other, can also be readily produced for special purposes, where a full coating on both sides is unnecessary, or may, in fact, be undesirable, as when spot welding is required. This operation can be carried out with less need for electrode dressing when the coating in contact with the electrode is thin rather than when it is thicker.

The fact that electro-galvanised steel can not only be formed, but also spot-welded and soldered, increases its versatility. In certain cases complete car-bodies have been made from it, since being clean and dry there is no grease to remove before painting is carried out, and neither does rusting occur in storage where painting is delayed for any reason.

The plant used for the electro-galvanising of steel sheet and strip is of a special nature, and a number of large installations are in operation throughout the world. Most of these lines are designed to process wide sheets rather than strip, since few users are capable of handling strip up to 52 in. in width. However, there is no essential difference between the two types of plant, apart from the fact that a strip unit has coiling and uncoiling gear at each end, which adds considerably to its cost. Strip plants are also provided with flying shears which cut the strip into sheets at the end of the line.



CONTINUOUS ELECTRO-GALVANIZING LINE FOR STEEL SHEETS (DIAGRAMMATIC)

Fig. 17.

The most practicable way of transferring the steel sheets from one processing tank to another is to keep them in a horizontal plane throughout the sequence of operations, which consists, in a typical installation, of eight alkaline cleaning tanks, eight sulphuric acid pickling tanks, eleven zinc plating cells and chromate treatment tanks. Rinsing is carried out between each operation, rubber scrapers being used to remove excess water. Finally the sheets are dried in a tunnel by means of hot air and cooled by cold air to prevent "sweating" in storage. All the cells are designed with a slot at each end running almost the whole width of the cell, with rubber strips to restrict leakage through the openings. The steel sheets then pass horizontally through them between slatted plastic tunnels which act as guides. In the case of the plating cells, provision is made for the cast zinc anodes which are placed above and below the sheets. The solution which runs out of each cell through the slots is collected into tanks, filtered and pumped back to maintain the correct level of solution above the surface of the steel.

In the alkaline cleaning and pickling cells, both of which are electrolytic, the sheets form the anodes; the cathodes in the alkaline cells consist of perforated steel plates with plastic strips acting as insulators and sheet guides, whilst in the pickling cells, lead plates perform the same function. The distance between the sheets and the anodes is only $\frac{5}{8}$ in. so that a high current density can be employed, and uniform deposits obtained.

Electro-galvanising lines are designed to operate at speeds of up to 60 feet per minute, but higher speeds are possible. At each of the transverse points between the cells (approximately 40 in number) pairs of driven rollers serve to move the sheets, the correct pressure being maintained on the rolls pneumatically. In the electrolytic sections of the plant, the bottom roller adjacent to each cell is a conducting stainless steel one, the plating current being fed to the sheets through suitable sliprings from the rectifiers; all the other bottom rollers and all the top rollers are rubber covered.

The plants are around 200 to 300 feet in length, the current being supplied by large rectifiers having

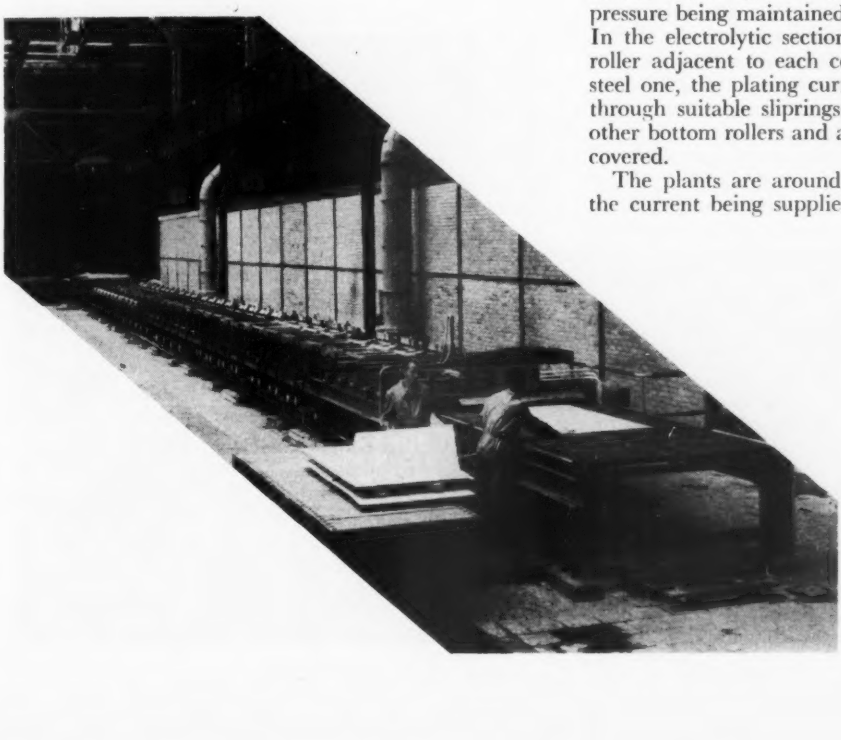


Fig. 18. Continuous electro-galvanising line for steel sheets. (Courtesy: Electro-Chemical Engineering Co. Ltd.)

a capacity of 60,000 amps or more, depending on the size of the installation.

A thin chromate conversion coating after plating is an essential part of the process and ensures that good paint adhesion will be obtained. Phosphating can also be carried out after galvanising instead of chromate treatment. Fig. 17 shows the layout of the plating line diagrammatically. In Fig. 18 a plant can be seen in operation.

The best method of paint treatment on electro-galvanised steel is to use an etch primer type of paint in the first instance to give good adhesion. The thickness of the paint film need not be as great as that required on plain steel to obtain adequate corrosion resistance. It is desirable, in fact, to limit the thickness of paint since heavier films have poorer adhesion characteristics, particularly under conditions of high humidity.[11]

electro-tinning of steel strip

Perhaps one of the most remarkable developments in the use of electro-plated coatings has been the silent revolution which the process has accomplished in the manufacture of tin-plate. Tin-plate is produced on a vast scale and is the most widely used material for canning and for the packaging of food products because of its low cost, attractive appearance and the non-toxicity of the metal. Tin-plate has other applications where conditions of service are not too severe, by virtue of the moderately protective value of the tin coating (which can be improved by lacquering) and because it is readily soldered and joined by other methods, as well as lending itself to decoration by printing and lithography. Up until the last War, practically all tin-plate was produced by the traditional method of dipping previously cleaned and pickled thin steel sheets into molten tin, usually by hand, although some degree of mechanisation of the dipping process had been accomplished.

Apart from its slowness, the limitation of the hot dipping process is that coatings of less than $1\frac{1}{4}$ lb. per base box cannot readily be produced. (The term base box is traditionally used in the tin-plate industry to denote 112 sheets of tin-plate 12 in. x 20 in. or an equivalent area.) The usual standard thickness is nearer $1\frac{1}{2}$ lb. per base box corresponding to a thickness of about 0.00012 in. of tin coating. For most applications this amount of tin (which is an expensive metal) is unnecessarily lavish, and the shortage of tin which developed during the last War gave the impetus to the introduction of electrolytic tinning methods, since this enables deposits of almost any thickness to be produced. In practice, the bulk of the tin-plate produced in this way has a coating corresponding to about $\frac{1}{2}$ lb. per base box, or 0.00004 in. in thickness, and this is adequate for most general purposes. It is thus seen that the method results in a vast saving of tin, and nowadays well over 75% of the world's tin-plate is produced by electro-deposition. When it is realised that this amounts to more than 6 million tons per annum, the vast scale on which electro-tinning is carried out can be realised. So far as the user is concerned, the product is not visibly different from that produced by the older method, whilst its fields of application have not changed appreciably. Hence, the introduction of the electro-tinning of sheet and strip has had a less marked impact than it might otherwise have done, and has in fact passed almost unnoticed outside the tin-plate industry itself.

The advantages of high-speed plating, the ready control of the thickness of the deposit and its uniformity, coupled with the fact that the steel can be handled continuously in coil form, have now made this to all intents and purposes the standard method of production.

The three main types of electrolytic tinning lines are based on (1) the alkaline sodium or potassium stannate bath; (2) the acid stannous sulphate-phenol-sulphonic acid bath; and (3) the acid stannous chloride-fluoride (halogen) bath. The great majority of continuous electro-tinning plants use the acid sulphate process.

The acid processes have the advantage that one-half as much current is required to deposit a given weight of tin from the bivalent electrolyte than from the quadrivalent stannate bath whilst efficiencies and current densities are higher; anode difficulties are also less likely to occur than with alkaline solutions.

As against these points, alkaline electrolytes are cheaper, have a greater detergent action, and being substantially non-corrosive, the cost of the plant and ancillary equipment is less. The bath is also somewhat easier to control.

In alkaline and tin sulphate processes, the strip passes vertically in front of the anodes in deep tanks. The halogen plants, on the other hand, are of the horizontal type, in which the strip passes over the anode placed below it, two tanks being used successively so that one side of the strip is plated at a time.

In one horizontal line which can run at a speed of up to 1,300 feet per minute, and uses the horizontal system, the steel strip arrives in the form of coils, about $5\frac{1}{2}$ feet in diameter, the material being 0.005 in. to 0.015 in. thick and up to 36 in. in width, each coil containing about three miles of strip and weighing 12 to 15 tons. At the entry end of the line the strip is uncoiled and passes through a welding unit which serves to weld the end of each roll on to the beginning of the next. Pinch rolls then transfer the coils through the plating tanks, where each side is plated separately, after which the coating is "re-flowed" by induction heating, quenched, and recoiled. Finally, it is cut into sheets, inspected, classified and piled. Both acid halogen and alkaline solutions have been employed in plants of this type, the pre-cleaning cycles being modified according to the type of solution used.

In the United Kingdom all the electro-tinning lines are of the acid stannous sulphate type, such as have been described by Frenkel.[12] The strip travels through deep plating tanks in a vertical plane at speeds of about 1,000 feet per minute. Pre-cleaning is carried out in an alkaline cleaner, followed by pickling in weak sulphuric acid, spray rinsing and scouring with fibre brushes. It is then ready to enter the electrolyte, where plating is carried out at up to 400 A/ft.^{2}.

The tin anodes are suspended vertically on both sides of the strip and are about 5 ft. long. They are inserted new at one side of the tank, whilst the worn ones are removed at the other; in this way they are moved horizontally across the face of the strip, which is travelling vertically. Provision is made for the additional thickness of the new anodes as compared with the worn ones to ensure that the anode-cathode distance is kept constant.

The current is conveyed to the strip through water-cooled conductor rolls. The anode efficiency of the plant is practically 100%, the cathode efficiency being seldom less than 95%.

The matt tin-plate as it emerges is " reflowed " by resistance heating to produce a bright finish as described below.

One of the advantages of electro-tinning is that it is practicable to produce coatings which are heavier on one side than the other. Hence, for the canning industry, a relatively thicker coating can be used on the internal side of the containers, the usual ratio being 4 : 1. A marking system is used to differentiate between the two sides.

re-flowing procedure

The tinned sheet as it emerges from the bath has the characteristic matt surface of the electro-deposited metal. This finish is not acceptable to the tinplate trade, so that it is necessary to "re-flow" the deposit by momentarily melting by suitable means. This operation also causes the tin to alloy with the steel base forming an intermetallic compound, $FeSn_2$, and gives a highly reflecting, easily solderable coating.

Modern plants use either high frequency induction heating, or resistance heating, or a combination of the two for "re-flow" of the tin deposits. In the resistance method, which is most widely used, the strip is passed between a pair of conductor rolls at the bottom of a melting tower, which is in the form of an insulated muffle furnace to reduce radiation losses. The heat input is controlled in relation to line speed, width and gauge of strip. The second conductor roll is immersed in a quench tank through which cold water circulates, so that the strip is quenched immediately after melting. This is necessary to ensure that only a thin alloy layer is formed, which results in an adherent, readily solderable coating. In higher speed lines where the required rate of heating cannot be obtained by conductor rolls, supplementary heating can be supplied by induction.

Electric resistance heating provides a satisfactory method of re-flowing the tin, provided careful precautions are taken to prevent damage at the contacts between the rolls and the strip. The power consumption is considerable, up to 3000 kVA and a furnace 60 feet long being required for a line speed of 1,250 feet per minute. [13]

For induction heating an oscillator of about 100 to 200 kW. capacity is necessary where a strip speed of 1,000 feet per minute is to be dealt with. The heating zone need be only about 10 to 12 feet in length.

after-treatment

After re-flowing, the tin-plate is passed through an aqueous solution usually containing chromic acid or dichromates to eliminate the staining and darkening of the sheet which occurs in lacquering or printing unless this is carried out. Such discoloration is due to the porosity of the thin coat which exposes the lacquer to the underlying steel. The passivating effect of the treatment eliminates this.

The chromic acid treatment consists in spraying a jet of a solution of 0.5% to 1.0% of chromic acid at 180°F on to the moving strip, after which it is rinsed and dried. However, a more satisfactory method is to use a cathodic electrolytic treatment in a 40 g/l solution of sodium dichromate at 165 to 195°F. The anodes are of low-carbon steel, located about $1\frac{1}{4}$ in. from the strip itself. The current requirements are 40

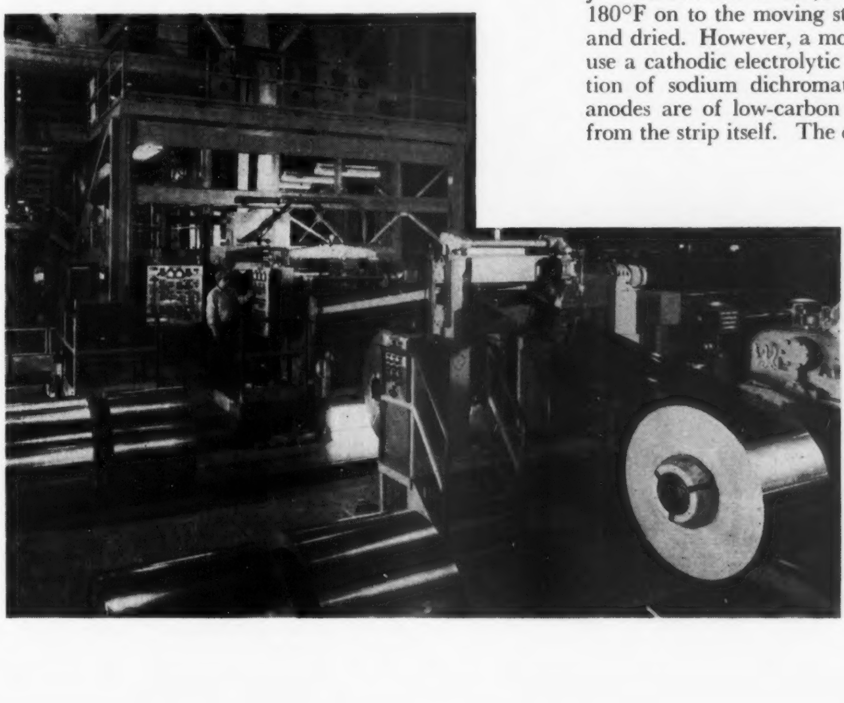


Fig. 19. Coil feeding system of the entry end of a continuous electro-tinning line. (Courtesy: Wean-Miles Ltd.)

coulombs/ft.^{2} and the pH, which tends to increase during operation from 4.2 to 6.5, is checked and controlled by addition of chromic acid. The strip is then thoroughly rinsed and dried.

As a final operation, the strip is given a thin, uniform coating of cotton-seed oil, palm oil, or dibutyl sebacate. The oil, which amounts to about 0.15 g. per basis box, helps to reduce finger marking and corrosion, and facilitates sorting and handling of the sheet and any subsequent printing or lacquering operations. The usual method of applying the oil is to flood a dilute emulsion of the oil in water on to the surface of the strip at 130° to 150°F. The amount can be controlled by the temperature, the oil deposited being less at lower temperatures. Electrostatic oiling is also employed; in this system the oil is atomised through fine spray nozzles by compressed air in a separate chamber, and attracted on to the strip uniformly by the application of a high voltage electrostatic charge between the spray gun and the strip. The latter is at earth potential, the high voltage wire electrodes being at a negative potential of about 70,000 volts. Automatic control of the variables ensures the application of a uniform film. Sometimes a combination of the two systems is used.

Finally, the strip is either re-coiled or sheared into sheets; the latter procedure is more common as many users find sheets more convenient. The shears are of the rotary drum type and are equipped with roller levellers; they are capable of cutting lengths of 18 to 40 in. at speeds of up to 1,000 feet per minute with a length accuracy of $\pm$ 1/32 in. The sheets are automatically tested for thickness and pinholes using beta-ray equipment, and are also visually inspected. In this way defective sheets are automatically rejected and separately piled.

If the plate is to be sold in coil form, it is simply rewound. Provision can be made in this case for an autographic record of each coil to be made as it is automatically inspected, so that the user can arrange for pinholed or defective sections to be cut out on the can-making or printing plant.

Fig. 19 shows the entry end of a large electrolytic tinning line, a general view of the cleaning and plating tanks and the control panels being seen in Fig. 20.

anodised aluminium

Anodising is not an electrodeposition process, although the techniques involved in carrying it out are similar in many respects to those involved in electroplating. It is more in the nature of a conversion coating, inasmuch as the surface of the metal is converted to a highly protective and tenacious form of its oxide. Anodic treatments have been experimented with on a variety of metals, but anodising on a substantial scale is confined to aluminium because

Fig. 20. Cleaning and pickling tanks, and control panels of a continuous electro-tinning line.

(Courtesy: Wean-Miles Ltd.)

of the characteristics of the oxide film which can be produced on this metal.

Aluminium, although highly resistant to corrosion, can become an unsightly drab grey in colour on exposure to the atmosphere. Under more severe conditions, white corrosion products may also form with deterioration of the metal surface. The anodising process increases the thickness of the oxide film normally present on aluminium and is carried out by making the metal the anode in a suitable electrolyte such as chromic acid or sulphuric acid. It is particularly suitable for the treatment of some of the harder aluminium alloys which are especially susceptible to corrosive attack.

The colour, hardness and physical characteristics of the anodic film can be varied within limits by using different electrolytes or anodising conditions. Film thicknesses of up to 0.0015 in. are obtainable by the sulphuric acid processes, but the coatings employed in practice are only 0.0004 to 0.0006 in. in thickness. The earliest anodising process, based on the use of chromic acid, was developed by Bengough in 1924 primarily as a protection for aluminium-magnesium alloys exposed to seawater; the coatings which are yellowish in colour are very thin (about 0.0001 in.) since the chromic acid has only a slight action on the film. Sulphuric acid attacks aluminium oxide slowly and thicker coatings can be built up because of the porosity of the anodic film which enables the reaction with the underlying metal to continue.

The sulphuric acid process gives a colourless film which has a mordant action for certain dyes, so that attractive coloured finishes can be obtained by immersing the anodised aluminium in a boiling solution of a suitable dyestuff. Finally, the film is sealed by treatment in boiling water, or dilute solutions of certain chemicals such as nickel acetate, after which the dyestuff will not leach out. The sealing process is an essential part of the anodising treatment, and must be carried out whether the film is dyed or not to obtain the maximum protective value. The mechanism of sealing is apparently dependent on the hydration of the oxide film by reaction with the hydroxyl ions in the water.

A variety of attractive colours can be obtained by the dyeing of anodised aluminium, but most of these are not permanently stable on exposure to sunlight. Greater durability can be obtained by the treatment of the anodic film before sealing with solutions of inorganic salts, such as ferric ammonium oxalate, which give a range of gold and brown shades. The colours obtainable in this way are limited in number, and the process is largely used for architectural applications of aluminium.

Anodic treatment is now extensively employed on aluminium where it is necessary that it should retain its appearance in service on such articles as domestic appliances, motorcar accessories, and builders' fittings. The importance of the process is such that in many fields the use of aluminium would not have attained its prominence but for the availability of the anodising process. Anodising also increases the durability of aluminium under the action of water and chemicals, and for this reason the interiors of such items as kettles and the bowls of washing machines have been anodised. For decorative applications anodising is often carried out after chemical brightening in suitable solutions.

conclusion

The electroplating processes described in this Paper constitute the most important protective applications of electrodeposits, but there is a variety of other special coatings which are also used. Silver plate is not only decorative, but has the advantage of non-toxicity and besides being the most widely used finish for cutlery and table-ware, is also applied to other metals as an electrical contact material. Rhodium, a hard non-tarnishable metal in the platinum group, is also used as a deposit which is employed where durable electrical contacts are necessary; palladium is used to a lesser extent for similar purposes.

For resistance to sulphuric acid, lead plating is employed on brass accumulator terminals and foam type fire extinguisher parts. For bearings, lead or lead-tin alloy deposits are extremely useful, and these are sometimes further plated with indium which is infused into the lead.

The field of electrodeposition is a fascinating one, and its potentialites are constantly being explored on an extensive scale throughout the world. New methods and applications are being introduced at a considerable rate, and it is likely that even greater advances will be made in the coming decade than in the last one.

acknowledgments

The author is indebted to Mr. C. Frenkel of Wean-Miles Ltd. for information on present day practice in the electro-tinning of steel strip, and to Mr. H. C. Castell of International Nickel Co. (Mond) Ltd. for some of the microphotographs.

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DISCUSSION

In the chair: Mr. G. RONALD PRYOR, President

Dr. G. S. Brosan (*Middlesex County Council Education Committee and Vice-Chairman of the Institution's Papers Committee*), opening the discussion, said:

Mr. Silman has given us a Paper in which the main points of value, as far as I am concerned, are the descriptions of automatic plant. It is with this in mind that I would like to ask Mr. Silman one or two questions.

When, a good many years ago, I was running a plating shop, I could never get an accurate estimate of the time required to process an article. If we had an article which required pre-polishing, plating and final polishing, it was only by, in effect, a pre-production run, or by comparison with similar components which we had processed before, that we were able to make a reasonable guess at:

(a) what sort of production one could get out of what facilities there were; and
(b) what sort of cost this would entail.

The two obviously go together.

I would like to ask Mr. Silman if there is any experience on which we can draw to give us an estimate of output and of cost and compare that with the capital investment required on automatic plant. In short, how does automatic plant compare economically with the older methods? There must be an advantage, but perhaps he could elaborate on what it is.

Another thing I would like to know about is the maintenance of these plants. What sort of frequency of maintenance is required? What sort of reliability is there?

Another interesting thing that Mr. Silman has mentioned is duplex plating and triplex plating. I imagine that eventually we will have a whole multiplex of systems ending up with an infinite number of layers with zero thickness. Be that as it may, what are the economic advantages of this? From what Mr. Silman has said in the Paper, I imagine that another layer of nickel will involve not only another nickel plating but, in fact, a number of cleaning operations, which would seem to me to put the cost up substantially. Would it be more economic to put on simply the thicker layer of ordinary nickel plating to give the same life? In short, how does this tie up economically with the older methods?

Mr. Silman: Dr. Brosan has given me material for another Paper, equally long, if not longer, and he has raised a number of extremely pertinent points.

The first thing I would like to say is, as far as output is concerned in relation to a hand-operated line, it is absolutely impossible to guarantee the output of such a line. You can calculate the time during which an article should be in the tank, the time to transfer it, and the time to handle it, but the total output is indeterminate, depending to a large extent on the operator concerned.

The output on an automatic machine is absolutely guaranteed. That is one of the principal reasons for its installation. The day when automatic machinery for plating was employed simply to reduce labour has gone. In fact, if one were to attempt to justify the installation of automatic plant simply on account of direct labour saving, I do not say in every case, but in a good many cases, it just would not work out. The other advantages of mechanisation are the over-riding considerations.

The reliability of modern automatic plating machinery is extremely high. Originally, perhaps before the War or shortly after, automatic machines were designed individually, using many different mechanisms, so that considerable teething troubles were encountered in each particular installation. Today, automatic plating machines can be of a highly standardised design, and by a simple modification of the sequence, it is possible to use a similar basic piece of equipment to do almost every kind of job.

One of the ways in which this has been achieved is by developments in the plating processes themselves; a plating process which has a high degree of versatility can be fitted into the mechanical part of the system much more easily than is the case with a highly sensitive and specialised plating process, that can only operate within very close current density and other conditions. The reliability has been achieved largely as a result of a high degree of standardisation and the experience that goes with the use of standardisation.

So far as the dual nickel processes are concerned, let me say at once that the object of introducing them nowadays is generally to improve quality. The plating industry went through a long phase when the entire emphasis was on increasing output and reducing cost, and no one paid very much attention to quality. Now the emphasis is on quality, and many of these newer processes are, to a certain extent, more expensive to carry out than the older ones. In view of competition, and the need to improve the general products of the industry, manufacturers are increasingly prepared to expend more money and effort. This applies not only in this industry but to many

others, and standards are increasing all the time. It is possible, to some extent, to achieve a similar result by increasing the nickel thickness, because this is the biggest single factor in plating quality. It is satisfactory to find that this country has pioneered the first labelling scheme to enable plating quality standard to be recognised by the customer, and we now have in the shops goods plated to a standard and labelled accordingly. One of the difficulties about plating is that you cannot tell how it is going to last by looking at it.

Mr. R. E. Mills (*S. E. Opperman Ltd.*) : I find it very refreshing to hear a Paper by someone who is obviously so much a master of his own subject that he is not frightened of voicing knowledge covering the whole field, from elementary principles up to the higher and obviously more complicated modern application of this information.

I am rather glad of this opportunity to say a few words, because I have rather a hobbyhorse on plating. I have been worried for many years by what, to me at any rate, appears to be a peculiar attitude of mysticism which surrounds plating people. As a designer, I always, like most designers, look for the engineering application of a material or process, but unfortunately, when it comes to plating, there never appears to be anything particularly precise or controllable. I will give you an example of that : plug gauges. If we want a plug gauge hard chromium plated, we cannot just plate a plug gauge. We have to grind it afterwards to obtain the correct dimensions. Similarly, when a component is built by plating, a further machining operation has to take place to produce the final dimensions. In your Paper, you talk about thicknesses considerably less than a tenth of a thou. Consequently, I cannot understand why tolerances to the order of, say, half a thou., cannot be easily maintained. I appreciate that plating does not build up the same all over, but I would like to point out that I have never seen any research work to try and overcome this difficulty. That is my first question and it is one I would like to hear answered.

There is another point in the Paper which I would like explained, primarily because I always understood, as illustrated by your title, that plating was developed to protect materials against corrosion rather than to be decorative. For the life of me I cannot understand why it is considered necessary to protect the protection, especially when the second protection is so unprotective. To put this in simple words, it appears to me most peculiar that one should want to protect plating with lacquer or something like that.

The second question is perhaps a little facetious. A constructive answer to the first question would, I think, be of value to a lot of people.

Mr. Silman : I do not think there is any mysticism today about plating. It is an extremely well-documented subject. In this country, there are some half-dozen journals which publish a vast amount of information at all times. If you find that there is any mysticism, it is because you are talking to mystics.

As far as plug gauges are concerned, there is a very simple answer to this. When one builds up any substantial degree of thickness of deposit, there is a real problem in getting the deposit uniform and accurate; it can be done. There is no doubt that, given the time and the trouble, one could get the exact dimensions that you want on a plug gauge, but it would be a very difficult and expensive operation. On the other hand, if you get an approximation to the thickness you want, and grind down, this is cheaper and you get the same result. It is as simple as that : just weighing up the relative costs of two different ways of achieving the same result.

So far as protection of plating by lacquer is concerned, I presume you refer to the people who put pink lacquer on their car bumpers to keep the rain off to prevent them going rusty. This is a policy of despair, and anyone who produces plating that requires lacquering to protect it should not be in business. Likewise, anyone who paints a car with a lacquer that requires waxing to prevent the paint from deteriorating, equally does not know his business. Such treatments should not be necessary.

Mr. Lacey : It is difficult not to ask questions about plating motorcars. I would like to refer to the introductory statement where Mr. Silman refers to the reduction in weight of motorcars by the production of plating : weight has been increased by having to add steel to support vast areas of plating.

In the bearing industry, we have to plate something like a thou. thick to very close tolerances, and we have not yet been able to go over to automatic processes; and we are very familiar with the troubles Mr. Silman talks of — the difficulty of control.

I wonder if Mr. Silman could say a little more on methods of testing, particularly non-destructive testing, because, where one is employing operators on these processes, it just is not possible to employ a high level of process control. At the moment, the only real way to test is destructively.

With regard to anodising aluminium, while one can readily anodise aluminium sheet, there are difficulties existing in anodising aluminium die-castings. The situation is that the alloys are the most readily die-cast and they are the ones most difficult to anodise. The presence of either copper or silicon in an aluminium alloy seems to result in grey or brown discolouration. Is there any possibility of the development of anodising work on this problem?

Mr. Silman : To deal with the question about non-destructive testing, there has been a good deal of research, and one or two devices are available which can enable non-destructive tests to be carried out on many base metals with certain coatings. Amongst these are a thermo-electric device, developed by the British Non-Ferrous Metals Association, and the well-known magnetic induction method. They are both commercially available. They have their limitations, one of the greatest of which is their price, but there is no doubt that they are finding increasing use.

On the question of anodising die-castings, as I pointed out, the durable anodic film itself is charac-

teristic to aluminium. Aluminium happens to produce an oxide of this tough and resistant form. Die-castings contain many metals such as copper and silicon which will not anodise, so that films on these alloys must inevitably be inferior in durability and also in appearance.

Mr. McFarlane : In a firm with which I was until recently connected, they had quite a lot of trouble with their machines in certain areas of the world due to corrosion in the damp, humid atmospheres. For these particular areas, their plated parts were of copper, nickel and chromium, in that order, instead of their ordinary nickel and chromium protection. Mr. Silman has spoken with regard to duplex nickel. Could he perhaps tell me whether duplex nickel and chromium would be better than copper, nickel and chromium?

Mr. Silman : This is the vital question which is at the back of the whole operation. Copper, nickel and chromium has been a standard process for many years; although frequently the copper undercoating is omitted. It has been found that the dual nickel coating gives better corrosion resistance than the earlier process under certain specific conditions. In view of the extreme difficulty of carrying out true comparisons, since outdoor exposure and accelerated tests vary so much, it is impossible at this stage, to make any catagorical statement that, under all conditions, dual nickel will be better than a copper-nickel-chromium deposit. I think it is safe to say that it is not likely to be any worse. The problem which arises, is whether it is worth all the trouble to introduce this system for a benefit which may well be only marginal. We shall know the answer to this in due course, no doubt, when more experience has been accumulated.

Mr. G. Cubitt-Smith (*Crompton Parkinson Ltd*) : We have a problem with tools used in the instrument works where the tools are handled frequently by the operators, are then stored for a short while, and a rust film develops on the tools. Is there any protective process that we can apply to the tools without giving a dimensional change on the tool?

Mr. Silman : Corrosion resulting from perspiration of the hands is a very formidable problem and a difficult one to overcome. Many plated coatings which are otherwise extremely good, such as cadmium or zinc, are susceptible to this form of attack. Other deposits, particularly chromium, are relatively immune. A measure of success has recently been achieved in Germany by the use of a cream which, when applied to the hands, inhibits perspiration, so that the plated articles are protected in that way. I know that this is transferring the onus from one place to another, but it is a method well worth looking into. There is, admittedly, some reluctance on the part of operators to use such creams, and I do not think they are much used in this country.

Mr. S. Critchley (*Skefko Ball Bearing Co. Ltd.*) : One aspect of corrosion which has not been mentioned in the Paper, which would not normally come into the protection range, is fretting corrosion. Has Mr. Silman any information on the effect of fretting on chromium plated surfaces? Has he any indication, in his experience, of the wear of a chromium surface on a shaft on which a bearing or a ring is fitted? If so, could I have some information on that?

With regard to the anodising of aluminium, what would be the coefficient of friction of an anodised surface? Is any information available of the surface height measurement after anodising, in regard to wear resistance? What would be the effect in regard to wear resistance of the material if that surface was to be used as a rubbing surface in a bearing or component of that type?

Mr. Silman : In the first place, I have no knowledge whatever of fretting corrosion occuring in the case of chromium plating. It may occur, but I have not heard of it being a problem with chromium.

The coefficient of friction of anodising surfaces is not particularly low, but I am afraid I cannot give you the figures off-hand. There are, of course, hard anodic coatings which are very useful for wear resistance, and have, in fact, been specifically developed for the purpose. They differ in appearance from the normal coating, being much darker, and they are usually applied from solutions kept at very low temperatures. There are companies which specialise in these processes, some of which are patented.

The **Chairman :** Can you give us a little more detail about the two processes you mentioned for inspection?

Mr. Silman : The thermo-electric method of measuring the thickness of a coating simply depends on the fact that when a temperature gradient is created between two different metals, a small electric current is generated. Heat is applied to the plated metal by means of a hot probe and the current produced as a result of the application of this heat, after thermal stability has been achieved, can be used as a measure of the thickness of the coating by calibration. The detailed operation of the method is, however, somewhat tricky and has taken a considerable time to work out. Such devices are available commercially.

Other methods depend on the magnetic characteristics of the coating in relation to the underlying metal, but are only applicable to magnetic coatings on non-magnetic bases and *vice versa.* They depend usually on the variations in the magnetic flux in the core of a transformer when it is placed in contact with the specimen, thickness readings being obtained from a calibrated meter in the transformer secondary coil.

The **Chairman :** The question I had in mind, of measurement of quality, was not of thickness but of quality of porosity of the overlay and the adhesion of it to the parent metal underneath.

Mr. Silman: As I indicated, the porosity of the coating is an exceedingly difficult thing to measure, because most of the methods of measuring it by actual tests on a coating which is not stripped off can actually create porosity in themselves. Methods of measuring inherent porosity have been developed in which the coating is stripped off and then tested. Such methods as gas permeability and beta ray penetration have been used but here again, there may be difficulties, because once a coating has been stripped off, it is different from a coating which is firmly adherent.

So far as adhesion is concerned, there is a variety of methods of measuring this, all of which are somewhat complicated and difficult. One method is to plate a very thick coating on to a deposit, which is then attached to a screw. The two metals are pulled apart, the force required being measured. Generally, the degree of adhesion of an electro-deposited coating is very high indeed and failure is very seldom due nowadays to lack of adhesion, unless there is something radically wrong with the plating process.

Mr. Collins (*London Transport Executive*): Could Mr. Silman explain just what are the difficulties in respect of chromium plating on aluminium? In 1939, I bought an aluminium teapot which was chromium plated and it withstood every kind of mal-treatment in the kitchen for about 20 years. It was really the most satisfactorily plated article I have ever had anything to do with and yet today, in 1960, somehow chromium plating on aluminium does not seem to be a good thing at all. Could we have some explanation of what the difficulties are?

Mr. Silman: Let me say at the outset that, as a generalisation, I would say there has been no deterioration in the chromium plating of aluminium as a process. In fact, there is reason to believe that there have been considerable developments and improvements since those days. I think it is dangerous, if I may say so, to go from the particular to the general. We have all had experience with things that have failed. I would not like to say as a result of an unfortunate experience that nickel and chromium plating of aluminium is worse today than it was before. In fact, all the evidence I have is to the contrary.

Mr. G. R. Blakely (*G. A. Harvey & Co.*): I would like to ask Mr. Silman whether it is not a fact that a far greater proportion of engineering products are protected, ignoring painted work, by hot dip galvanising than by plating? In the Greater London Area alone, something like 1,000 tons of work a week is, in fact, hot dip galvanised, and is therefore given protection against corrosion for anything from 10 - 15 years upwards on location.

I would also like to ask whether I would be correct in believing that fabricated and welded items and assemblies would be completely beyond the possibility of the electro-plater, either physically or economically.

Mr. Silman: I would not question the statement that a vast amount of steel is hot dip galvanised.

So far as the plating of assemblies is concerned, I do not think it is true to say that such a procedure is impossible. In fact, complex assemblies are frequently plated in the assembled condition. Ordinary brass taps, for example, are nickel and chromium plated regularly as standard practice in the assembled condition, as are even flexible metallic tubes. I might add, however, that platers do not like it!

The **Chairman:** On behalf of the Institution, I would like to thank Mr. Silman for preparing this Paper, for coming here to give it to us, and particularly for the way he has answered the questions, which I am sure will have satisfied all the questioners.

Before I ask you to signify your appreciation in the usual way, I have a pleasant ceremony to perform. It is our custom to mark the occasions of these important national Papers which are given to the Institution and show our appreciation to the lecturer, by presenting him with a memento of the occasion. In this case, we have a silver rosebowl, which I hope Mr. Silman will accept with our best wishes.

Mr. Silman: May I say how appreciative I am of this magnificent gift to mark the occasion, although I consider the invitation to present the Paper in itself to have been a great honour.

The meeting was then closed.

Correspondence and comment on published Papers and matters of interest to production engineers are invited.
Communications should be addressed to:

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CONTRACT PLANNING IN THE BUILDING AND CIVIL ENGINEERING INDUSTRIES

by E. W. SPENCER

Head of Planning Department,

John Laing Construction Ltd.

A Paper presented to the London Section of The Institution of Production Engineers on 21st April, 1960

"TIME shall be of the essence of the contract." We have all become familiar with this clause. Today, the emphasis on speed of construction is providing the building and civil engineering industries with an exciting challenge. Construction problems provided by modern structures are not eased by the increased demand for speedier contract completions. The introduction over recent years of new types of plant, improved working methods and modern materials, allied to the application of planning, costing and work study techniques is assisting the industry to meet the challenge successfully. For this reason, I welcome the opportunity to tell you something of contract planning methods which are in current use within the industries.

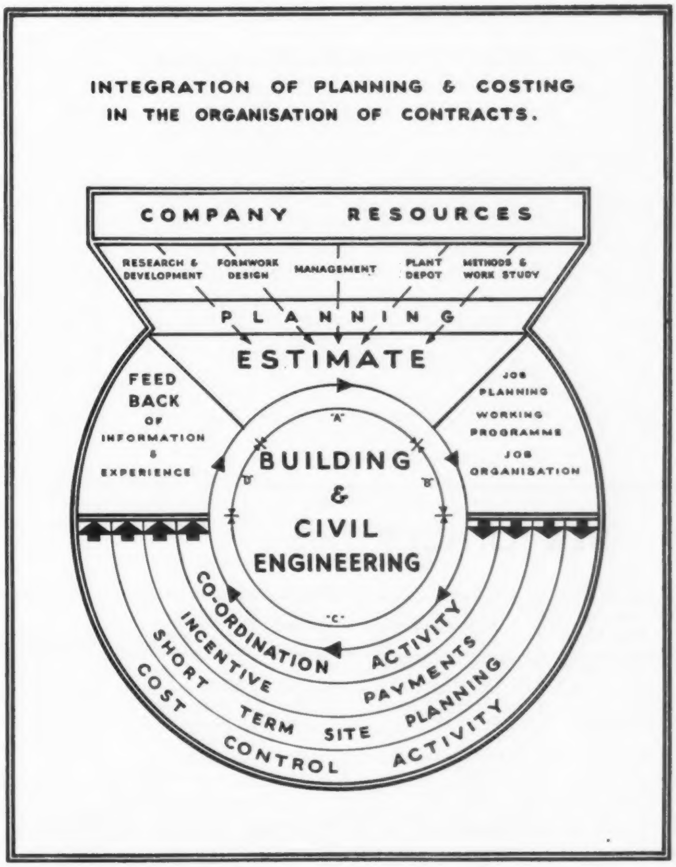
The introduction and development over the last decade of personnel who specialise in the provision of a planning service to both estimators and contract managers, has brought about a welcome change in the attitude of the industries towards the use of programmes and progress charts. They are no longer produced solely for display purposes but instead, their intelligent use as an aid to management is making a vital contribution to increased efficiency.

overall pattern of contract services

It has become the practice to provide a planning service at three main stages in the execution of an average contract obtained by competitive tender:

firstly, to the estimators at the time of tendering;

Fig. 1



secondly, to contract management immediately following the award of a contract;

thirdly, to contract management during the course of a contract.

Fig. 1 illustrates how these three stages of contract planning combine with other contract services, e.g., costing and work study, etc. It shows how these processes are integrated and used firstly at the tendering stage, then throughout the progress of the contract, and finally by the estimator as guidance for the future.

Let us refer first of all to Section " A " of the diagram. The job plan at this stage will be finally illustrated in programme form upon which the Estimator will base his estimate. The production af a plan and estimate will involve calling upon the services of specialists within an organisation for instance, Plant Development Engineers would be called upon to advise on the best machinery for the job. They would recommend whether rubber tyred or crawler tractor scrapers were best suited to the particular earth-moving project. They would recommend and design batching and concrete mixing plants with outputs capable of meeting programme requirements. They would advise on which tower crane out of a multitude of varying types would best suit the demands of the job in hand. Soils Engineers would also provide information regarding suitable aggregates which were to be found adjacent to the proprosed contract. In the event of information being required concerning ground conditions, they would carry out a full scale soils investigation. The result of such an investigation might very well determine basic construction methods which in turn would govern the Estimator's prices.

A formwork design department would be asked to recommend and design shuttering which the estimator would price.

Contract management would be called upon to give advice on proposed methods, thus enabling them to draw upon their previous experience.

A plant depot would be consulted regarding the availability of suitable plant.

A Method and Work Study Department would supply standards obtained from various studies taken on site as well as giving advice on methods or calculating labour requirements for unusual operations.

These are examples of company resources which might be called upon to provide specialist advice when an estimate is being produced. Much of the information obtained would be presented in chart

form by the Planning Engineer to illustrate the job plan.

This, then, would be the first stage when a planning service is provided.

Next, let us refer to section " B " of the diagram in Fig. 1. We should assume that the contractor has been awarded the contract. The Contract Manager is now officially appointed and together with a Planning Engineer, a Master Works Programme or long term plan covering the whole of the contract period would be prepared, once again calling upon the services of those specialist departments referred to at the tendering stage. In this way, the Manager would become familiar with the scope of the contract. He would at the same time be making arrangements for an early start on site. Job organisation, at this point, would involve the Manager, amongst other things, in ordering site huts, making arrangements for staff and labour to report to site, in addition to the ordering of plant and key materials. The existence of a programme at this difficult stage is vital to the success of the early job organisation and is the second stage when a planning and programming service is provided, this time to contract management.

Section " C " of the diagram indicates a few of the control procedures applied during the course of the contract, these being site functions as opposed to the previous which were head office functions. Firstly, there is the co-ordination activity which briefly is the work undertaken by site management to ensure that plant, labour, materials and drawings are made available to meet programme requirements. It might involve expediting the release of drawings from architects and engineers in accordance with agreed dates, and the notification of site programme requirements to sub-contractors and suppliers well in

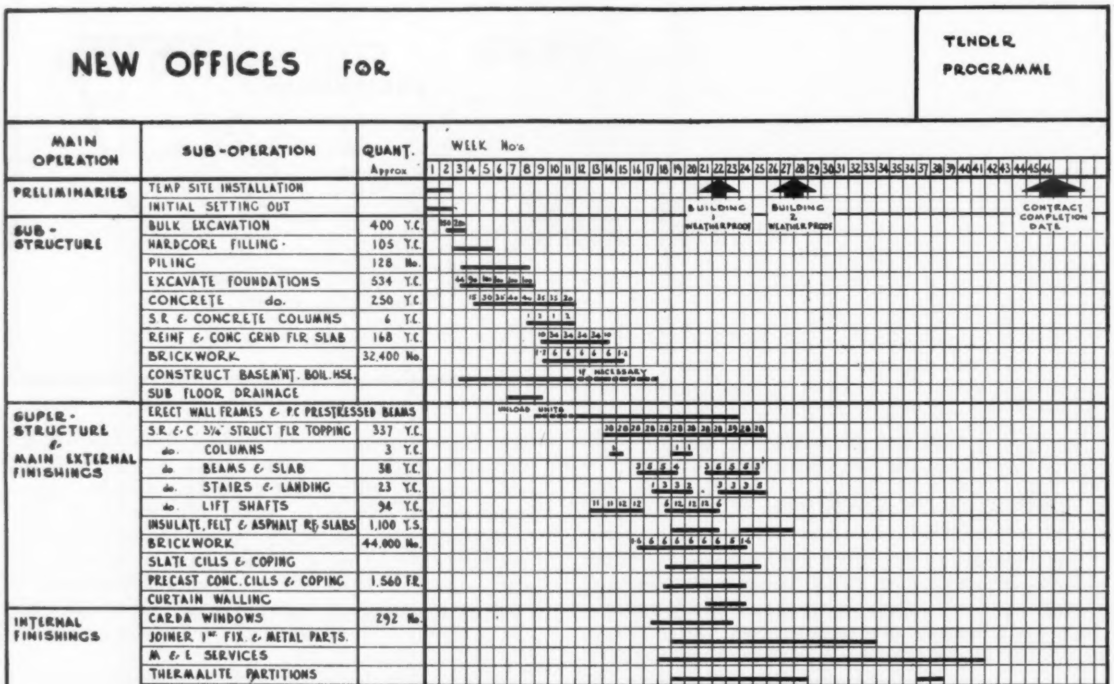


FIG. 2

advance, followed by periodic inspection visits to check on the progress of off-site fabrication.

Site meetings involving the architect, engineer, quantity surveyor, contractor and major sub-contractors provide an opportunity for frank discussion of site problems by each representative and a review of action necessary to avoid delay. The organisation of such site meetings, together with the efficient recording of matters discussed and action to be taken, make a vital contribution to maintenance of progress.

Next we have the payment of bonus based upon the amount of work done over and above an agreed target, which we find to be an incentive to greater production. This bonus is calculated and paid on a weekly basis for each gang on measurable work.

Then there is short term site planning, which is the third stage of contract planning and consists of breaking down the long term master plan prepared at the commencement of the contract into short term plans covering a particular stage of the contract, to show in greater detail the work content and the labour requirements. This short term plan would form the basis for the preparation of weekly plans or targets.

Next, there are cost control activities comprising weekly or sometimes daily measurement of actual achievements and comparison with the standards of output upon which the estimate was based. An analysis of the reasons for departure from standard provides the Contract Manager with information from which he can watch for adverse trends and take corrective action as necessary.

Finally, in section " D " we have the feed back of information and experience as a continuing process. Details of actual achievements are fed back to Estimators and Specialist Departments for guidance in the preparation of future tenders.

So much for the overall pattern; now to take each stage of contract planning in greater detail.

tender planning

(a) objective

The first stage, it will be recalled, is when a planning service is provided to the Estimator at the time of tendering for a contract.

We are very often invited to price a bill of quantities based on an incomplete set of drawings and specification. The best way in which we can provide a service to the Estimator in determining the economic price for the job, is by the careful preparation of a job plan illustrated in the form of a tender programme.

(b) description of typical tender programme

Fig. 2 illustrates a typical tender programme prepared for a three-storey office block of about 28,000 sq. ft. By reference to the column headed " main operation ", we see that the construction has been divided up into packages embracing first of all the preliminaries, these being the initial operations essential to the commencement of the permanent structure but relating to temporary works only. Next we have the sub-structure, which includes operations contributing towards the completion of the foundations, usually up to and including the ground floor slab. The superstructure and main external finishings would relate to operations included in the erection and cladding of the building frame, on completion of which the structure can be regarded as watertight. The internal finishings are of course self explanatory and involve operations such as are undertaken by the plasterer, joiner, electrician, plumber, heating engineer and painter, bringing us up to the stage when the building is ready for hand-over to the client.

It can be seen that each of the main operations has been broken down into sub-operations to which quantities have been affixed. The time scale along the head of the programme is based upon week numbers only, since the actual contract starting date would not generally be known at this stage. The programme itself is of the bar line type, with the average weekly outputs of key operations indicated along the bar. These have been summarised at the foot of the programme to show estimated weekly outputs, in addition to the main plant requirements and the periods over which such equipment will be required on site.

(c) programme preparation

The time available for the preparation of such a programme is, of course, related to the tender submission date and does vary.

The first step of a Planning Engineer is to gain a thorough knowledge of the job by careful study of the bills of quantities, specifications plus all available drawings and correspondence. This will provide an opportunity for the extraction of all major quantities, and to ascertain whether or not there are any priorities or completion dates to be adhered to within the contract period. Prior to the detailed preparation of the programme, a site visit would be arranged in conjunction with the Estimator and a Senior Contract Manager responsible for the area in which the contract is to be situated. Such a visit would provide the Planning Engineer with an opportunity to check on actual site conditions and see for himself the access problems, ground conditions, and the extent of site clearance or demolition to be undertaken. The degree to which such items are likely to influence the programme cannot be measured from drawings and contract documents back in head office.

The next task would be to prepare the framework of the programme, including setting down the main and sub-operations plus the approximate quantities and a time scale along the top, followed finally by the detailed calculation of time periods for individual sub-operations. The final chart may not be especially elaborate but a great deal of research will have gone into its preparation, involving the Estimator and Planning Engineer in numerous discussions with specialist services and contract management of the organisation.

(d) main benefits of the programme

On completion, the programme should assist the Estimator in finalising his decisions on such items as:

firstly, the total contract period which he will require for inclusion in the form of tender;

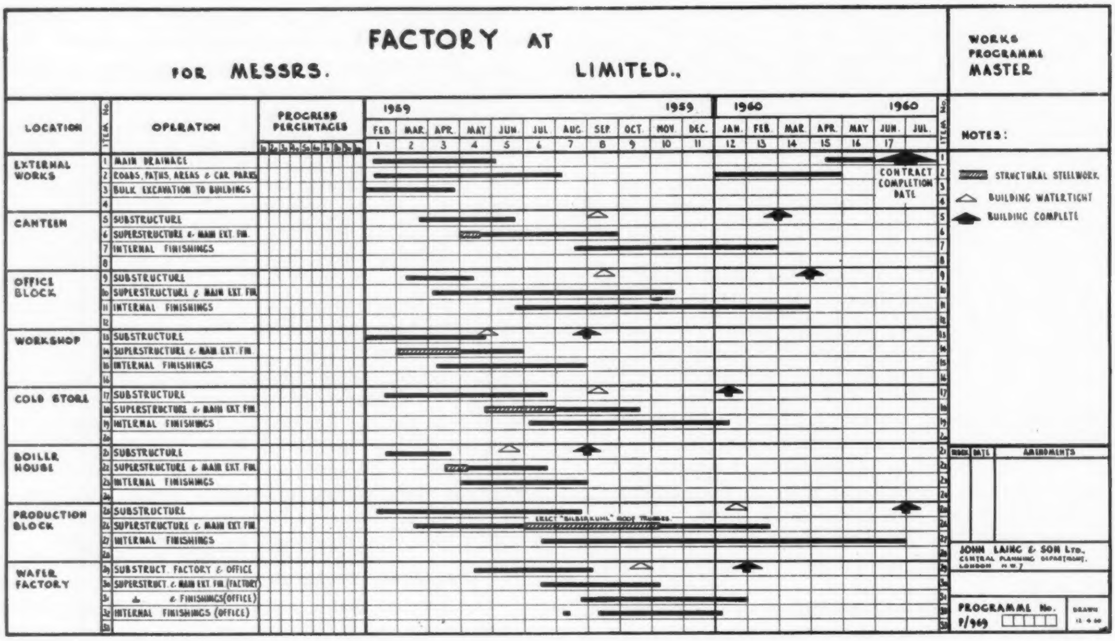


FIG. 3

secondly, the best sequence of construction to be aimed for in order to give maximum continuity for major items of plant and specialist trades;

thirdly, the estimated weekly outputs in respect of key operations, usually considered to be hand and machine excavation, concrete, shuttering and brickwork, there will be others, dependent upon the nature of the contract;

fourthly, the machines required and the length of time that they will be needed on site;

fifthly, the amount of shuttering required to conform to the concreting programme;

sixthly, the overheads—which he can assess in relation to programme demands;

seventhly, total labour requirements and importation charges to be set against the contract, i.e., when results of enquiries at local Labour Exchanges have indicated that the availability of local skilled labour will be limited and that it will be necessary to import tradesmen from other areas;

finally, the calculation of additional cost to be allocated to the tender should the client require the whole or parts of the contract to be carried out in an unusually short time. During the preparation of the programme, it would have become evident that special measures would be necessary to meet the required completion dates, and it is then that recommendations can be put to the Estimator on the introduction of such items as: overtime working, rapid hardening cement, additional labour, shuttering, or plant plus floodlighting.

Thus it can be seen that the tender stage planning has involved the predetermination of the broad issues in the job and subsequent illustration in bar line chart form.

job planning

(a) objective

The next important stage when a planning and programming service would be provided, this time to contract management, follows the award of a contract. It will be remembered that at the tendering stage, the job plan was illustrated in the form of a tender programme. The task is now to illustrate the job plan in the form of a works programme.

(b) description of typical works programme

Figs. 3, 4 and 5 represent a few typical works programmes which are in common use today. These programmes are also known as long term programmes and cover the duration of the contract or individual building.

Fig. 3 illustrates a master programme such as would usually be applied to a major contract involving a number of separate buildings. It provides a schedule of the time allocated to each of the main operations in every building, in addition to showing by arrows the individual dates when completion is required in order to comply with client's requirements. Whilst the principle of presentation remains the same as the tender programme (see Fig. 2) it can be seen that certain alterations have been made, such as the introduction of a percentage column for the recording of progress. Actual dates have been added in addition to the panel for amendments, whilst data relating to plant and weekly outputs has been removed. It should be noted that for each of the units indicated

in the column headed " location " an individual detail works programme is produced, a typical one being as illustrated in Fig. 4.

It can be seen that this programme is a far more detailed document than the tender programme, although the form is similar. It is the practice at this stage to include many more operations, particularly under the heading of " internal finishings ", than it would be necessary to consider at the time of tendering. A column has been introduced for the purpose of entering the sub-contractor's name following his appointment. Dates and contract week numbers are added at the head and base of the programme in addition to a brief description of works on the right hand side of the schedule.

It is becoming the practice to provide in addition to the job description a small scale elevation or plan of the job, which is proving to be very useful during programme discussions. The introduction of a number of symbols in advance of the bar lines within the programme will have been noted. These, very briefly, are the latest dates by which drawings, schedules and nominations of sub-contractors are required to enable progress to be maintained in accordance with the programme. I shall refer to these in greater detail at a later stage.

Fig. 5 shows a very different style of programme which is being applied on an increasing number of occasions. Very simply, it is the programme expressed in graph form and lends itself particularly to the contract of fewer operations involving large quantities, such as a motorway. It can also be applied successfully to the contract where operations are of a repetitive nature such as a multi-storey building and this is confirmed by the illustration. The outstanding merit of this form of programming is its simplicity coupled with an immediate indication of the trend which is produced whenever progress is recorded. The rapid realisation that to proceed at the same rate will result in the completion date being overrun will cause the efficient Manager to take immediate remedial action, the extent of which can be more readily measured.

There is no doubt that, applied correctly, this form of programme can be a most effective control document, despite its simplicity.

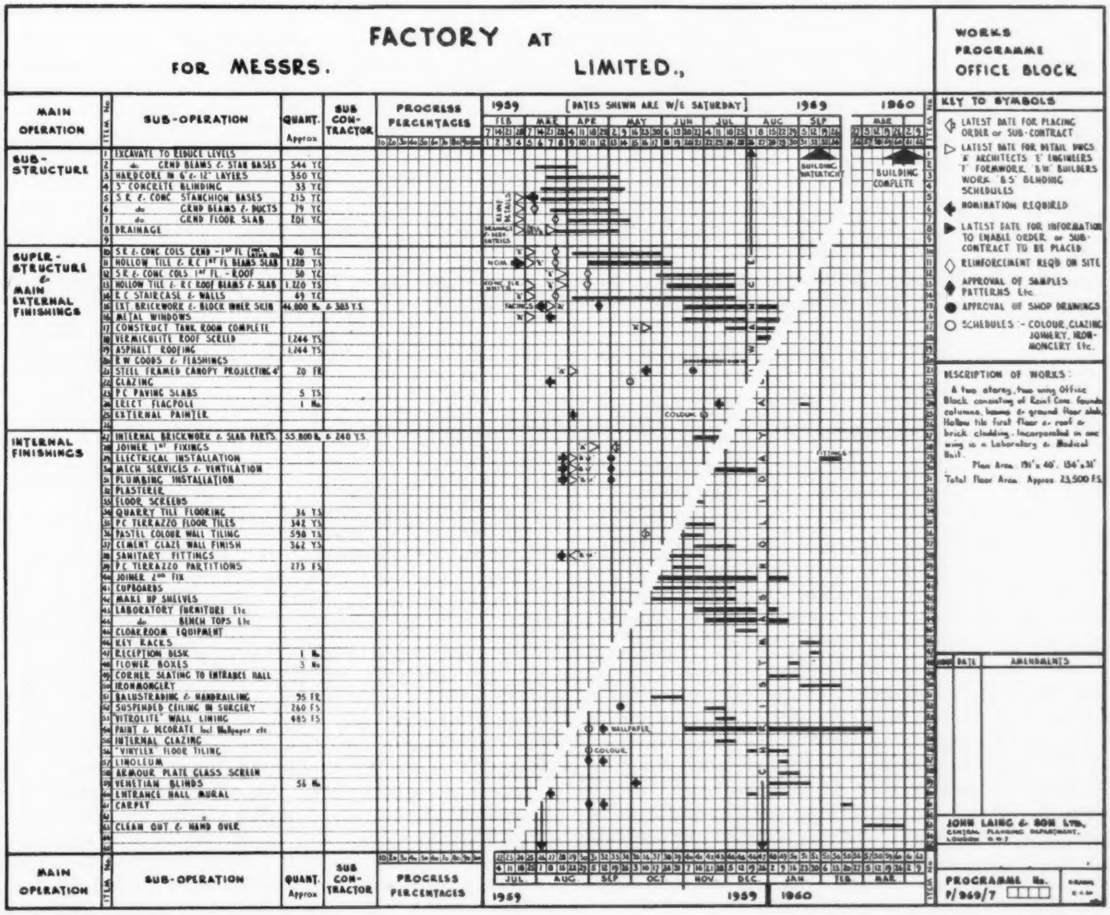


FIG. 4

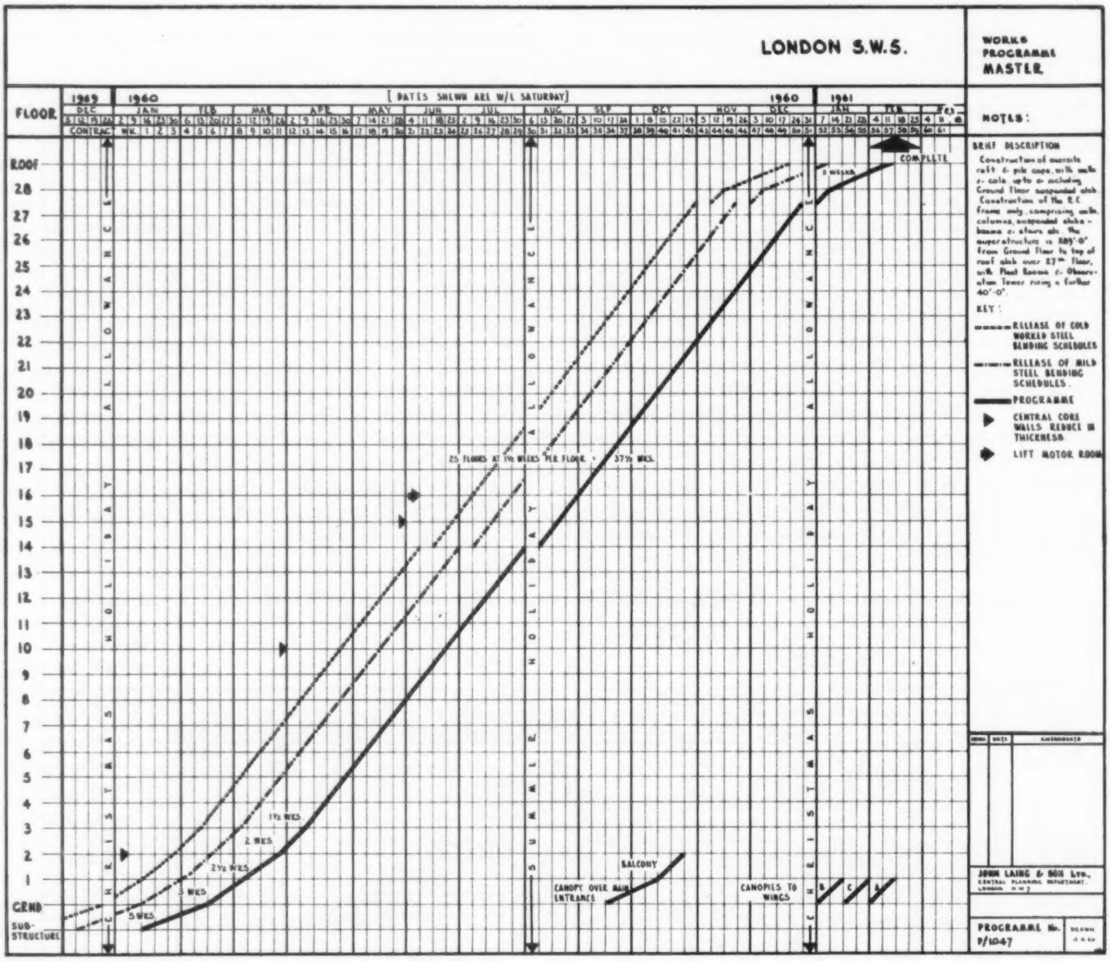


FIG. 5

(c) programme preparation

Having described a few typical long term programmes, I should like to deal now with the preparation of these charts.

Having received notification of the contract award, the next stage would be to gather together all the latest available data, including drawings, correspondence, bills of quantities and specification, plus the programme produced at the time of tendering.

Next, arrangements would be put in hand for the Site Manager appointed to the contract to spend a period with the Planning Engineer on the preparation of the works programme prior to the commencement of the contract. It will be appreciated that the Manager is thus enabled to study all the available data, to investigate and assist in the preparation of the works programme, and, as a result, to acquaint himself with the job before becoming immersed in site administration duties which are particularly heavy at the start of a contract.

With the Manager beside him, the Planning Engineer is able to finalise the programme, which involves settlement of methods, timings for individual operations, and sequence of operations, plus the consideration of continuity of working for key trades and major items of plant. In this manner the Manager plays a leading part in programme preparation and will obviously assume a greater responsibility for ensuring that progress is maintained in accordance with the programme.

It is especially important at this stage that allotted time periods are discussed and agreed with all major sub-contractors and suppliers involved in the job. I am referring here particularly to those sub-contractors around whom the programme revolves in the initial stages of the contract; e.g., dewatering specialists, demolition contractors, piling contractors, structural steel erectors, and the like. It may also be necessary to contact those suppliers and contractors whose products are in short supply, in order to obtain their agreement to the programme, even though they may

not be required until a late stage in the contract. I have lift installation specialists in mind here.

In addition to the works programme, a comprehensive report would be prepared and circulated. The intention of such a report would be to provide a resumé of all information so far obtained under a series of 30 - 40 headings, typical ones being contract description, value, programme, materials and sub-contractors, plant, staff and labour requirements and the like. Any outstanding information, together with decisions required to facilitate progress in the early stages of the job, would be included. Such a report, prepared quickly before contract commencement, can make a useful contribution to the success of a job in the early stages by informing departments of the scope of the project. The headings of the report would form an agenda for a pre-contract co-ordination meeting.

Returning to the works programme, we have now agreed this with the contract management. The next move would be to superimpose a very important programme in advance of the construction programme in the form of key dates.

(d) key dates for release of drawings and nominations

Fig. 6 is an enlarged extract from a typical works programme which is intended to highlight the key date system to which I referred earlier. These key dates indicated by symbols relate in the main to the latest permissible dates for the issue of outstanding drawings, nominations and schedules if the programme is to be maintained. You will appreciate that in order to arrive at these dates it is necessary first of all to have finalised the bar line programme and then to familiarise oneself with current delivery periods which will, of course, influence the length of time that orders have to be placed and in turn drawings issued, prior to an individual operation being commenced on site. It is not sufficient to add these key dates to a programme; we must, and do, arrange meetings with the architects and engineers concerned, in order to agree these dates. The provision of dates by a contractor for the release of drawings, enables the architect or engineer to finalise his own drawing office programme, from which he can ascertain whether additional designers are required to keep up with the progress dictated by the works programme.

The addition of these dates to the programme, and their subsequent agreement, is not the end of the story. They are being used by the contract management as a basis for progressing action and are included in the agenda of site progress meetings.

(e) progress recording

I should next like to tell you something of a system of progress recording which is in use. When describing the works programme I referred to the panel headed "progress percentages". As the work proceeds, the percentage of work is filled in and then transferred across to the bar lines on the chart bearing in mind that the time period allocated to any one operation is equal to 100% (see Fig. 6.). A line drawn vertically on the programme (from the time scale) at any stage (to which progress has been recorded) will immediately show the items which are either ahead or behind target.

It is then possible to estimate the number of weeks the contract as a whole is in arrears or ahead of the programme.

By arrangement between Head Office and the sites, a shuttle copy of the programme would be completed and returned to Head Office together with details of hold-ups, current and anticipated. The information drawn from the programme and the site progress

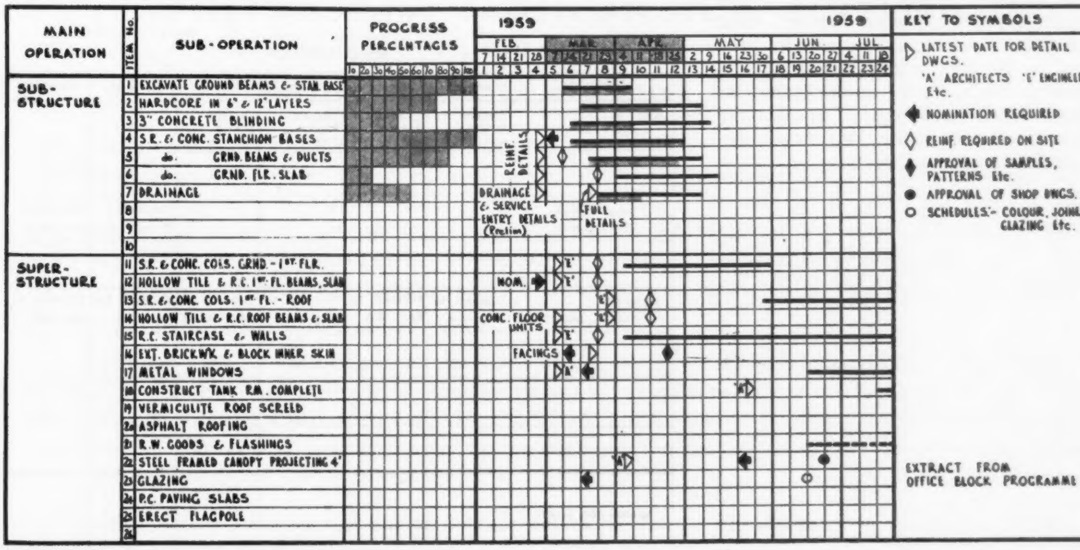


FIG. 6

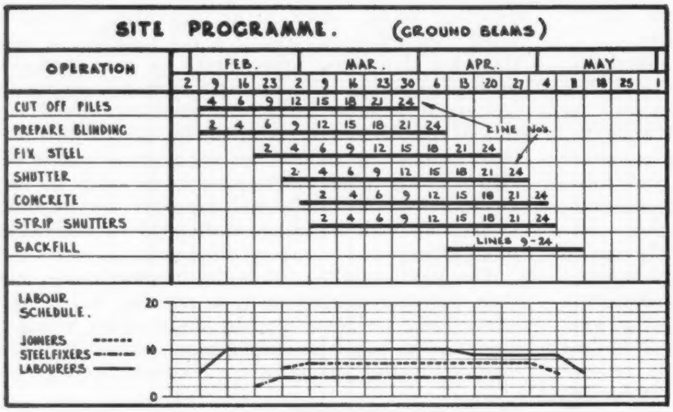


FIG. 7

report are put together in one overall progress report which becomes invaluable for chief executive staff at headquarters.

short term planning

The third stage mentioned earlier was that of short term planning applied during the course of a contract and consisting of a break-down of the long term or master plan into detailed short term plans covering important stages in a contract, e.g., the work between contract commencement and a key date which might be the commencement of structural steel erection or alternatively be between the commencement of super-structure and the date scheduled for a building to be watertight.

A typical short term plan would be as shown in Fig. 7 and incorporating a labour graph.

The whole object of the exercise is to illustrate in greater detail than the long term master plan the work to be done over the next two or three months, at the same time calculating detailed plant, labour and material requirements to enable progress to be maintained according to schedule. Such a programme would be related to the master plan and would also provide a basis for the preparation of weekly plans or targets.

These targets are illustrated in the form of a daily programme covering the next week's work and whilst a Site Manager would receive technical assistance in their preparation the contents will represent his instructions expressed in written form. A typical weekly plan is illustrated in Fig. 8.

Every Friday, the Manager together with his technical assistant and his formen would plan the work for the following week, the targets set having been based on actual achievements. This would be done in sufficient detail to ensure that:

(*a*) there will be no over-lapping or waiting between trades;

(*b*) the maximum use is made of machines, shutters, concrete outputs, etc.;

(*c*) the demands on concrete mixing and other major plant items are evenly distributed;

(*d*) the correct sequence of working is maintained;

(*e*) time is available for servicing plant, repairing and cleaning shutters, etc., without interfering with production.

When all the work has been allocated to gangs the total number of men involved would be checked

Week Commencing 4 April '60 — WEEKLY TARGETING — TRADE Joiners

Gang and Operation	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
SMITH SHUTTERING BEAMS	GROUND BEAMS LINE 7 to 8	GROUND BEAMS LINE 10 to 12	GROUND BEAMS LINE 13 to 15	GROUND BEAMS LINE 16 to 18		
SHUTTERING COLUMNS					COLUMNS to LINE 6	COLUMNS to LINE 6
JONES FLOOR DECKING	FLOORS to BAY 6A	FLOORS to BAY 6B	FLOORS to BAY 6C	FLOORS to BAY 6A	FLOORS to BAY 6B	FLOORS to BAY 6C
REASON FOR DELAY						

FIG. 8

against the weekly manpower return to ensure that every man on the job had been accounted for.

This internal weekly site meeting would provide an opportunity to review the progress of the past week followed by discussion and adjustment if necessary of the targets planned for the next week. In this way everyone knows the targets which have been set, the reasons why various lines of action have been taken and the detailed operations to be done by the men and machines in each section.

The site management would follow up the progress of the targets daily so that when difficulties arise which interfere with the achievement of targets, corrective action can be taken immediately to minimise the effect on the other sections of the work.

conclusion

Key material and labour shortages, more complex structures, the tendency for drawing issues to overlap to a greater degree with construction, plus increased competition in the industry, were a few of the factors which prompted the introduction and development of contract planning methods over the last decade.

It used to be argued that the labour difficulties which beset every Contractor at the commencement of a contract, plus the marked affect of inclement weather upon progress, were such as to render any plan unworkable. Today these two factors are no longer a deterrent to the preparation of a programme, but rather an incentive, inasmuch as the plan provides a yardstick against which the extent of lost time can be measured and the likely effect on the completion date calculated. The Contract Manager can then decide, together with the employing authority, on what special measures are necessary to recover lost time and get back on to programme. In addition to providing a yardstick against which to measure site progress, it will be evident that a programme is also used in the industry to indicate when drawings, materials and sub-contractors will be required as well as providing a basis for the calculation of labour and plant requirements.

As far as contract planning is concerned, a look into the immediate future is both exciting and encouraging. I see firstly an extension in the application of planning methods to include every contractor in the industry, irrespective of size, followed by refinements in present techniques, which will include an increase in the use of programmes expressed in graph form.

Planning techniques will be applied to a greater degree in the design stages before work starts on site. This will serve to reduce design time and ensure an adequate supply of the right drawings before the signal to start work is given.

More training schemes for future contract managers will include a period on planning and programming at both Head Office and on site. There is already a trend in this direction which is more than encouraging.

Such developments make me confident of the industry's ability to meet the challenge of even shorter contract periods in the future.

WHITWORTH FOUNDATION SCHEME

Awards offered to Practising Engineers

THREE Whitworth Fellowships for 1962 are being offered by the Ministry of Education to practising engineers who wish to follow a course of training, study or research at postgraduate level in an approved establishment or industrial organisation, in the United Kingdom or overseas. The awards are worth £1,000 a year, plus additions for dependents, travelling and subsistence where appropriate. In addition, three Whitworth Exhibitions of £100 will be awarded to unsuccessful candidates whose worth deserves recognition.

Applicants must be over 25 and in possession of a university degree in engineering, a Diploma in Technology (Engineering), a Higher National Diploma or Certificate in engineering with at least two distinctions, or of a qualification approved by the Minister of Education as of equivalent standard. They must have been subsequently engaged as practising engineers for not less than three years. Women who satisfy the conditions are eligible to compete.

Further details and forms of application are obtainable from: The Ministry of Education (FE3C), London, W.1, to whom applications are returnable by 31st July this year.

RADIOISOTOPES IN PRODUCTION ENGINEERING

by W. G. BUSBRIDGE

Principal Scientific Officer,
Isotope Division,
A.E.R.E., Harwell

Synopsis

The advent of the nuclear reactor and the nuclear power programme has facilitated the production, cheaply and in large quantity, of radioisotopes.

These are, at the moment, saving British industry over £3½ million per annum, and this saving could be increased many times if their advantages were better appreciated. The Paper details some applications of isotopes to production engineering, and suggests further methods of value in this field.

This Paper was presented to the Peterborough Section of The Institution of Production Engineers on 20th April, 1960.

THE first nuclear reactor in Britain commenced operation in 1948. The 12 years which have since elapsed have seen the growth of a new tool for industry, the radioisotope. Today, Britain exports radioisotopes to a greater value than those of all the other countries in the world combined.

The total British trade in radioisotopes, over £1,000,000 per annum, is not a true measure of their value, for the savings that they can achieve in industry and research of every kind is many times their cost.

the nature of isotopes

If the atomic weights of the 90 elements found on earth are arranged in order, it is found that, taking the atomic weight of the lightest hydrogen as the unit, very few are whole numbers, but that if the atomic weight of oxygen, normally slightly less than 16 on this scale, is taken as 16 units, a great many more atomic weights become whole numbers.

The atomic weight of hydrogen, however, now becomes 1.008.

This was explained by Frederick Soddy, in 1913, by suggesting that some of the elements, including hydrogen, are mixtures of two or more varieties of the element, of different atomic weights, and Soddy proposed the name " isotopes " for these.

Today, we know that the atomic weight of hyrogen, 1.008, is due to the presence of one part in six thousand of the isotope hydrogen 2 or deuterium, weighing twice as much as the commoner variety.

So it is found that of the 90 elements, 70 are mixtures of two or more isotopes.

The atom was first postulated as a small, indivisible sphere of matter, but it is now known to be like a

Fig. 1. In the silver plating of the rotor-face of the fuel pump used in the majority of gas turbine engines, the thickness of the plating has to be controlled to .0001 in. The only non-destructive method is by use of radioisotopes, and an instrument was developed by A.E.R.E., Harwell and Joseph Lucas (G.T.E.) Ltd. as the only standard means of determining plating thickness. Here it is being used to determine the thickness of silver plate on a G.T.C. fuel pump rotor face while an operator is preparing the rotors for the next operation of rotor bore plating. (U.K.A.E.A. Copyright photograph)

miniature solar system, whose centre is the nucleus, and around which revolve a number of electrons.

The nucleus carries most of the mass of the atom, the electrons weighing some thousands of times less than the nucleus.

The nucleus itself is found to consist of two types of component: protons, each carrying a positive charge and normally equal in number to the encircling electrons, and neutrons, having no charge, but of almost the same weight, whose number can vary between narrow limits.

The naturally occurring isotopes differ from one another in respect of the number of neutrons in the nucleus, the "mass number" giving the total number of nuclear units—protons and neutrons together.

Thus iron is a mixture of four isotopes, Iron 54, 56, 57 and 58, which occur in a fixed proportion regardless of where the iron is found. Tin is a mixture of ten isotopes and mercury of seven.

atomic number

The number of protons in the nucleus is a very important characteristic of the element, the atomic number. It is this which marks the nature of the element and (because the encircling electrons, the same in number, take part in chemical reactions) controls its chemical characteristics.

radioactivity

The phenomenon of radioactivity, discovered by Becquerel in 1896, is due to the instability of nuclei which contain more or fewer neutrons than the limits between which stability occurs.

This causes atoms to disintegrate from time to time, emitting some nuclear particle which alters the mass and/or the electrical charge, thus bringing the nucleus nearer to a state of stability.

In 1934, Joliot and Curie discovered that it was possible to render normal stable elements radioactive by bombarding the nucleus with neutrons, thus altering the proton/neutron ratio. This was at first done using neutrons generated by bombarding appropriate targets with the radiations from radium.

Today the nuclear reactor, which supplies vast quantities of neutrons from uranium fuel, enables artificial radioisotopes to be produced cheaply and in large quantity.

The fuel of the reactor is also a source of radioisotopes, as when it releases its energy it is broken down into a complex mixture of isotopes, of about 40 different elements, known as fission products, many of them radioactive.

Some of these may be profitably extracted for commercial purposes, or the mixture of fission products may be used as a source of radiation.

half-life

Every radioisotope has its characteristic half-life — the time taken for half the atoms present to disintegrate. Thus, in two half-lives, one-quarter of the atoms remain; in three half-lives, one-eighth.

In 10 half-lives the measure of radioactivity is reduced over a thousandfold, and in 20 half-lives over a million times.

Of the vast numbers of atoms in even a minute quantity of a radioactive isotope, every one is just

Fig. 2. Using a liquid gauge on CO2 cylinders.
(U.K.A.E.A. Copyright photograph)

Fig. 3. A Beta thickness gauge is used to grade a steel sheet at the Velindre Works of The Steel Company of Wales. (U.K.A.E.A. Copyright photograph)

as likely to explode as any other — it may do so within the next second, or it may be a million years before it does so.

Radioactive decay, therefore, is a chance process and no chemical or physical changes can alter the rate of decay or, therefore, the half-life.

Three kinds of radiation are usually emitted by radioisotopes, and are known by the first three letters of the Greek alphabet. Alpha radiation consists of nuclear particles each composed of four units, two protons and two neutrons, and therefore identical with the nucleus of the element helium 4.

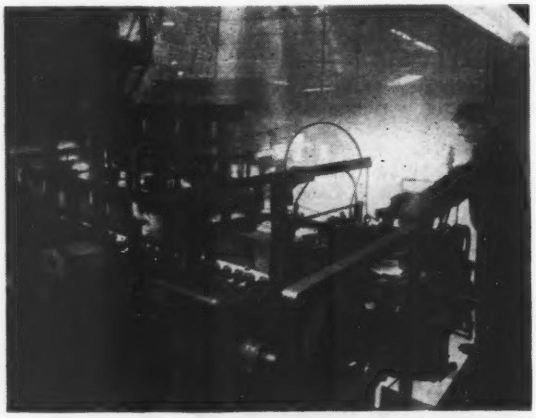


Fig. 4. At the Rockware Glass Factory near Doncaster a nucleonic liquid level gauge made by Isotope Developments Ltd. records the level of the molten glass in the furnace. The gauge is designed to indicate the level of liquids in industrial plant under drastic conditions of temperature pressure and corrosion. Here the box on the left is a detector which measures the amount of gamma radiation from a radioactive source placed on the opposite side of the forehearth channel. The amount of radiation it indicates is proportional to the level of the molten glass. This enables the furnaceman to maintain the correct level of glass in the furnace. (Crown Copyright photograph)

Alpha particles are only emitted by very heavy nuclei such as those of the natural radioisotopes, radium, thorium and uranium.

Beta radiation consists of high speed electrons manufactured in and emitted by the nucleus in an endeavour to achieve stability by getting rid of a negative electric change and thus converting one of the neutrons in the nucleus into a proton.

The emission of an alpha or a beta particle therefore alters the proton content of the nucleus, causing a transmutation of the nucleus to that of a different element; in the case of alpha emission, to one with an atomic number two less than that of the original nucleus; in the case of beta emission, to one with an atomic number one higher.

Gamma radiation, which is often a sequel to alpha or beta decay, is an electromagnetic radiation similar in nature to X-rays, whereby the nucleus can dissipate excess energy remaining after the emission of an alpha or a beta particle.

Alpha and beta radiation can be slowed down and stopped by matter, alpha particles by a sheet of paper, or in their passage through a few inches of air; beta particles by a fraction of an inch of metal or a few feet of air.

Gamma radiation, however, being electromagnetic, is attenuated by matter, but may be detectable after passing through several inches of solid metal or stone.

the detection and measurement of radiation

The first instrument for detecting radiation was the spinthariscope of Sir William Crookes, in which the observer counted the flashes of light resulting from the impact of alpha particles on a fluorescent screen in a darkened room.

Today a variety of instruments is available.

Among the most important are the Geiger counter, in which the passage of a single nuclear particle or a single quantum of gamma radiation initiates an electric discharge, the scintillation counter, in which flashes of light on a fluorescent screen or in a suitably transparent crystal are registered by a photomultiplier, and the ionisation chamber, in which the conductivity of a gas, such as air, is used as a measure of radiation to which it is exposed.

All these instruments can be connected to an integrating circuit, which records the total number of particles or the total amount of radiation received, or to a ratemeter which indicates the intensity of radiation.

tracer techniques

Just as a dye may be added to a liquid flow system to study the rate of movement, so radioisotopes may be used to study flow, movement, uptake or wear and can be "seen" through the walls of pipes or vessels by one of the many available forms of detecting equipment.

One gram of, for example, sodium 24, emits over three hundred thousand billion beta particles per second. If we can detect or measure one beta particle per second (which is not difficult to do) we can therefore detect or measure to one three hundred

thousand billionths of a gram of the isotope, an accuracy and sensitivity many millions of times greater than that prevailing in chemical or spectrographic analysis.

Radioisotopes have been used, therefore, to study the flow of blood in the human body, the mixing of foodstuffs and chemicals, the transit and leakage of gases and liquids in pipelines and chemical plant, the movement of silt and shingle in harbours and estuaries and the flow of water in rivers and irrigation systems.

The use of material of short half-life ensures, weight for weight, maximum detectability, while the effective duration of radioactivity is short and techniques of this nature may be used, if necessary, in the manufacture of commodities, with the assurance that no appreciable radioactivity will remain by the time they reach the hands of the customer.

In some cases it is more convenient to form the radioisotopes *in situ*.

Thus, by placing piston-rings in the nuclear reactor and irradiating them with neutrons, the radioisotope iron 59 is produced. When a piston ring is replaced in the engine, its rate of wear can be measured by the rate of growth of radioactivity in the lubricant by transfer of the iron 59. Such methods enable comparative wear tests to be carried out in a fraction of the time normally required for tests based on weighing or micrometry, and during the short period of the test the relevant mechanical conditions, such as load, coolant temperature and dust feed can be accurately controlled.

Where material is transferred, irradiation analysis is sometimes of value. In this, the components are irradiated after use, and the transfer of foreign material can often be detected and measured as one of its radioisotopes. A typical problem that can be examined in this way is the examination of the transfer of material from a cutting tool to the work.

thickness and depth gauging

The intensity of radiation received from a source diminishes with distance, in the same way as light, obeying the universe square law.

Radiation is also absorbed by matter, and some of it is reflected and "back-scattered".

These effects have been successfully applied to a variety of gauges for measuring the thickness of material or the depth of liquid in a vessel.

Continuously produced sheet materials, such as paper board, linoleum, sheet steel and plate, may be measured without any contact with the surface.

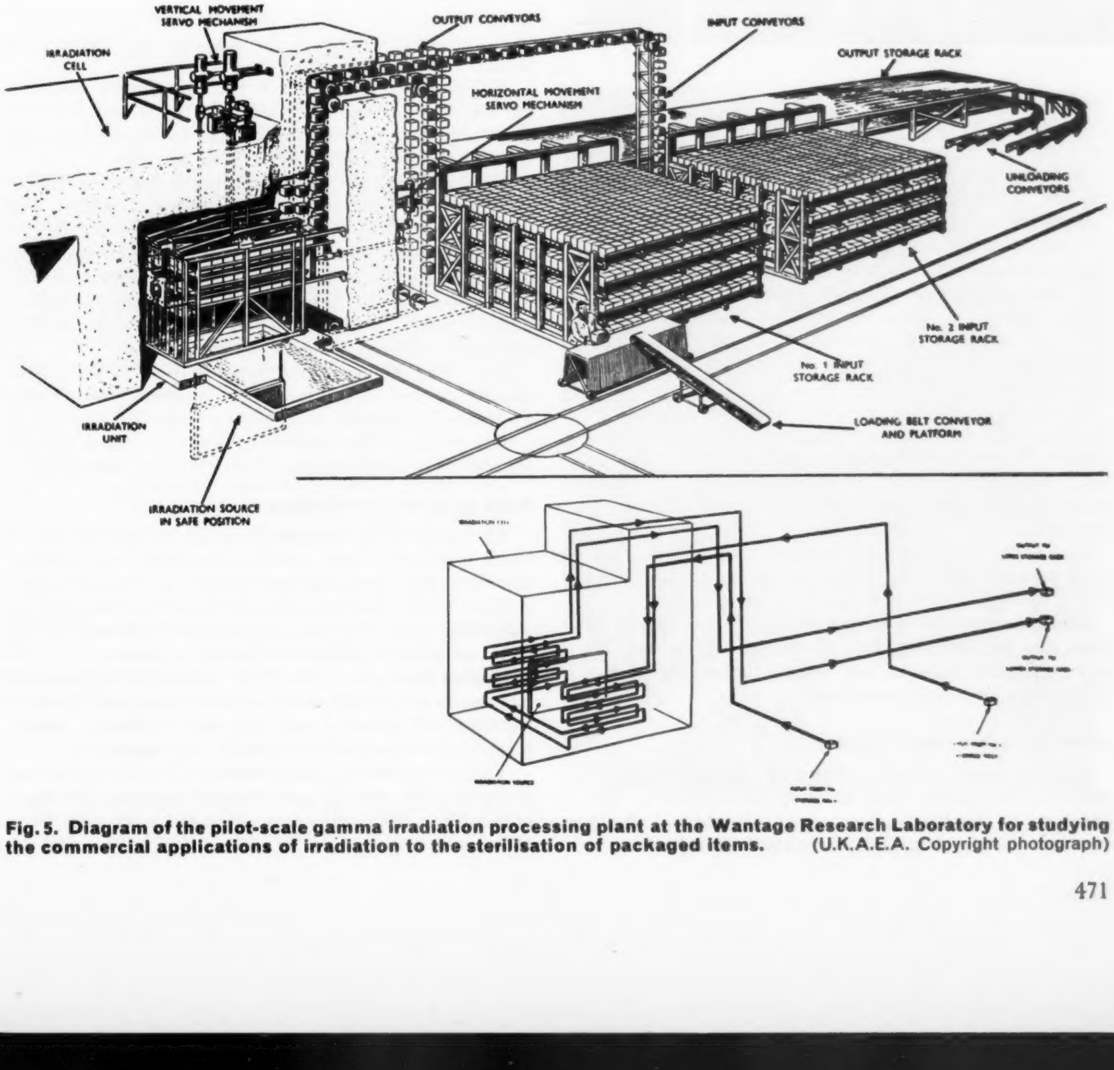


Fig. 5. Diagram of the pilot-scale gamma irradiation processing plant at the Wantage Research Laboratory for studying the commercial applications of irradiation to the sterilisation of packaged items. (U.K.A.E.A. Copyright photograph)

Fig. 6. A four-high rolling mill finishing brass strip, with a nucleonic thickness gauge in the measuring position over the running strip. When the tail strip has passed, it will be moved aside automatically for calibration before the next strip enters. Any thickness error is fed back to the screw-down motors which control the strip thickness. The Strontium 90 source is below the strip, the photomultiplier tube in the casting seen above.
(Photograph by courtesy of Baldwin Industrial Controls, *Baldwin Instrument Co. Ltd.*)

The material may be measured in a soft or friable state, or in the case of a metal, while it is white hot, and the thickness reading may be relayed to the roll-spacing control to give immediate correction.

Such methods lead to quicker production because it is unnecessary to stop the production line for gauging; there is no loss of material of incorrect thickness; less manpower is necessary for gauging and inspection; supplies of bulk material go further because none is wasted in overweight production, and the guaranteed uniformity of the material gives it a higher market value.

Using "back-scattering" the thickness of platings of zinc, tin, chromium or nickel can be measured directly. A thickness gauge, operating from one side only, permits the direct measurement of boiler shell walls or pipe walls which may have been thinned by corrosion.

The measurement of liquid level in a closed vessel may present problems, particularly when the liquid is hot or highly corrosive, or is a liquefied gas.

By measuring the attenuation due to the liquid to the radiation from an isotope source, which may be mounted externally to the vessel, the depth of the liquid may be easily measured.

photographic applications

A developable image is produced in a photographic emulsion by alpha, beta or gamma radiation. The emulsion is, therefore, an extremely simple and cheap method of recording and integrating radiation.

Much use is made in industry of small pellets of gamma-emitting radioisotopes, such as cobalt, iridium and thulium as substitutes for an X-ray set in industrial radiography.

The gamma radiation is selectively attenuated to different extents by the different thicknesses of metal in, for example, a casting, and by placing behind it an X-ray film in a casette or dark slide, a radiograph is obtained which may show faults, flaws or blowholes.

The cost of such radiographic sources is only a fraction of the cost of the X-ray equipment which they replace, and their independence of electric power enables them to be used in the field, under water, and in many other circumstances in which the use of conventional high voltage X-ray equipment is impracticable.

A choice of sources of different energies is available and gives control of the contrast obtainable with subjects of different thicknesses.

Cobalt 60 is suitable for radiography of castings or forgings in iron and steel up to about 8 in. in thickness. For lighter objects, up to about $2\frac{1}{2}$ in. in iron or steel, iridium 192 is very suitable.

For light castings in aluminium, or for such objects as electronic components, the isotope Thulium 170 is of value.

Exposures in gamma radiography are, in general, longer than those in X-ray practice, because the radiation from an X-ray tube is concentrated into a narrow beam, whereas the radiation from an isotope source is emitted in all directions.

However, where radiography is used as an aid to quality control in production, it is possible to arrange a number of objects, each with its own X-ray film, in a two- or three-dimensional pattern round the isotope source, thus facilitating a higher rate of handling.

bulk gamma irradiation

The adoption of programmes for the generation of electric power from nuclear reactors has greatly increased the potential production of radioisotopes.

They may, as has already been mentioned, be extracted from the fission products into which the uranium fuel breaks down in the reactor.

During the early life of the fuel, also, the reactor has excess reactivity, and the excess neutrons need to be absorbed by some material such as boron, which has a large capture cross-section for neutrons.

This is replaced in some reactors by materials such as cobalt 59, which, on neutron capture, becomes cobalt 60, a beta and gamma emitter with a half-life of 5.3 years.

The facility to produce such materials cheaply and in large quantity enables gamma radiation to be used as a catalyst in chemical reactions.

Many reactions proceed faster and to different end points under gamma irradiation.

Polymerisation of long chain molecules is aided. Rubber molecules can be directly cross-linked without the need of sulphur or accelerators, giving a rubber whose cure is only progressed by the minute amount of natural background radiation, whereas thermally cured rubber continues to cure slowly at normal temperatures, causing it to become overcured, and thus limiting its life.

In the pharmaceutical industry, many materials, such as antibiotics, which are destroyed by heat, can be sterilised by gamma radiation after they have been packed in sealed containers, thus avoiding the need for aseptic conditions of working which are costly to set up and difficult to maintain.

Similar treatment may be applied to surgical goods, such as dressings, sutures, hypodermic syringes and needles or catheters, which are sealed into an impervious envelope or container before being sterilised.

Radiation, it should be stressed, is in no way infectious and materials exposed to gamma radiation of the energies emitted by radioisotopes do not become radioactive any more than they would become luminous if exposed to light.

the economics of radioisotopes

Many industrial processes can be aided by radioisotopes with resultant economies which are many times the costs of the isotopes used.

A recent survey has been carried out among British industrial users of radioisotopes by Dr. J. L. Putman of the Isotope Research Division of the U.K.A.E.A.* to assess the savings which can be attributed to the use of radioisotopes.

Many firms were unable to make a firm estimate, but those who did so, with a total annual turnover of about 30% of the total of that of all the isotope users, returned a saving of over £660,000.

This represents a saving of about 79 times the costs of the isotopes used.

Since the survey was made, the price of isotopes has been raised, so that a saving of 50 times the cost of the isotopes is thought to be a reasonable obtainable result. The survey was conducted in very conservative terms, and excludes a great many intangible benefits, some of them of great financial value, accruing from the sale of radioisotopes.

Such a rate of saving spread over the British industrial users indicated a total net saving of over £3,500,000 for the year 1957 - 1958 and this could easily be increased to over £14,000,000 if the use of isotopes was universal in processes in which they have already shown worthwhile economies.

Sales of radioisotopes by the U.K.A.E.A. during the year ending 31st March, 1960, reached a total value of £1,100,000 of which 69% was exported.

* *"The Nuclear Goose Lays a Golden Egg"* by J. L. Putman. *The Director,* June, 1959.

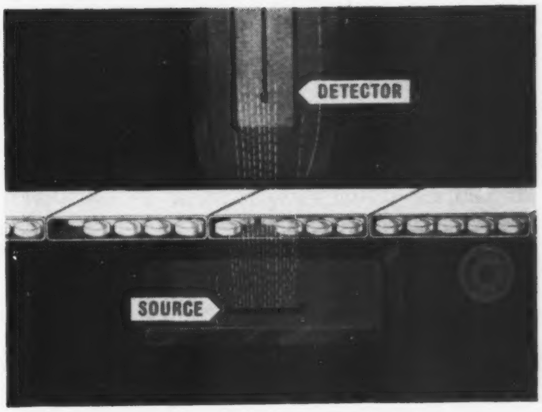


Fig. 7. Animation of tablet counting, showing detection of incompletely filled packages.
(U.K.A.E.A. Copyright photograph)

There is no doubt that radioisotopes can be applied to production engineering, resulting in an increased production rate and a better and cheaper product.

In Britain, where our export trade is so vital to the maintenance of our standard of living, it is important that their potentialities should be studied and used to their fullest extent.

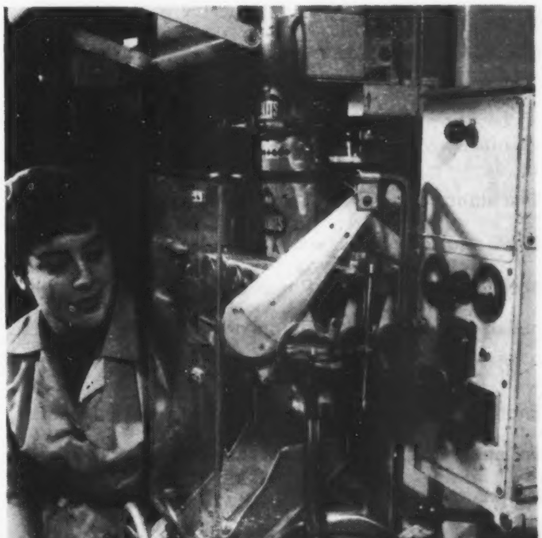


Fig. 8. A package monitor in use at a biscuit factory in Wales. (U.K.A.E.A. Copyright photograph)

SOME ASPECTS OF APPRENTICE AND GENERAL TRAINING

by C. JONES, A.M.I.Prod.E.

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The author of this Thesis was formerly with Radiation Limited for over ten years. After a period in Work Study he was appointed Tool Room Superintendent and ultimately was responsible for tool design and manufacture.

Mr. Jones joined Audco Limited as Works Liaison Engineer and following the successful establishment of an apprentice training workshop he was appointed Works Superintendent of a new factory producing specials. He subsequently became Research Methods Engineer, and is responsible for research and development in new methods of production.

IN order to appreciate the full significance and importance of the practical side of apprentice training, a short sojourn into the background of apprentice training is necessary.

Even during the 20 years between the two Wars, when mass unemployment was a chronic feature of the British economy, it was in general not difficult for school-leavers to find their first jobs. The big expansion of mass production, particularly in the consumer trades, opened up many avenues of employment for untrained workers and the low wages commonly paid to juveniles gave them an advantage over their elders. It is significant that Arnold Freeman, writing in 1914 on boy labour, mentions "semi-skilled" as a new term, and even the New Survey of London Life and Labour published in 1931 thought it necessary to draw attention to the rise of an intermediate class of semi-skilled workers unknown in the past, who obtained their training by moving up a "ladder of progressively complex processes". For such process workers steadiness and care, rather than skill in the craftsman's sense of the word, were required, and young workers could easily learn to do most of these jobs. By the middle of the First World War the proportion of boys to men had almost doubled in the building industry and had increased by 50% in engineering.

Whilst mechanisation increased the proportion of jobs that can be done with little formal teaching or experience, it also brought into being the demand

for skill of the highest order to make the tools and to set and maintain the complex machines operated by the semi-skilled. For this highly skilled nucleus of workers, apprenticeship, supplemented by instruction in the technical schools, was still essential. There were other kinds of work which came somewhere between these two extremes, requiring more than careful repetition of a single process but not the comprehensive knowledge of those competent to deal with processes and intricate tools. For this group a period of learnership was customary; and these in their turn shaded off into occupations in which a worker without any definite instruction might be upgraded from simpler to more complex processes as he showed himself capable of undertaking more difficult tasks.

The First and Second World Wars did much to expand the proportion of repetition and process work to skilled craft work; for with the shortage of highly qualified men and the absolute need to increase production, particularly in the engineering industries, much inventive genius was concentrated on the task of breaking down skilled jobs into their consituent processes on which semi-skilled men and women might be employed. The Wars thus did much to accelerate the development which was already strongly under way, and opened the door in industries which had traditionally been considered highly skilled to workers with no particular qualifications. By the 'twenties, therefore, three separate ways of training recruits for skilled occupations were in force :

(1) apprenticeship

That is, a contractual relationship in the traditional sense in which the employer bound himself to teach a boy — or cause him to be taught — the trade or business, and in which the apprentice undertook to serve for a stated period of time at graduated wages which finished below the standard rate for the job when it was done by a skilled adult. Such a contract did not necessarily take the form of an indenture, nor was it always a written agreement of a less formal nature. A verbal undertaking in which both sides recognised the customary terms was sufficient, and in practice, this "gentleman's agreement" was by far the most usual type of contract. The essential part of it was the obligation on the part of the employer to see that the apprentice was taught all that a skilled craftsman should know (though sometimes this was customarily limited by acceptance of the fact that the employer could teach only that part of the craft that was carried on in his business and that the apprentice might equally have a limited capacity to learn).

In the days when apprenticeship was the only legal means of entry to a trade, it had been usual for fathers to buy their sons in by paying a premium for an indenture and though this is falling into general disuse, there are still a certain proportion of such premiums paid. The practice varied from trade to trade and region to region. Over 16% of shipbuilding apprentices in the mid-twenties had had premiums paid on their behalf, whilst in engineering there were only 5% - 7%, and in printing and building between 2% and 3%. Even so, the premiums were usually so small as to be almost " token ".

Apprenticeship was confined to relatively few occupations. It was found mainly in the engineering and allied industries, in shipbuilding, building, woodworking, printing and a few others.

(2) learnership

A form of training of comparatively recent origin. The learner was not an apprentice but was taken on for a specific period of years, usually less than that required for apprenticeship, and was given definite facilities to learn a branch of the trade or a particular process. The agreement was extremely vague, but the most important characteristic was that there was no specific obligation on the employer to teach but merely to allow the boy facilities for learning by watching others with whom he was in contact. This form of training was usual in textiles, boot and shoe and paper-making and in the group of industries covered by Trade Board regulations.

(3) upgrading

This was the practice of promoting labourers or unskilled workers to semi-skilled or even higher jobs as a result of learning by association with more skilled persons. A quick and observant man who had acted for some time as a " mate " to a skilled worker might, if there were a shortage of suitable workers, be allowed to try his hand during a sudden rush of work. If this happened fairly frequently, the less complex or less intricate parts of the craftsman's job might come to be left to him as a regular thing. During the latter years of the First World War this practice became more general, for the supply of fully qualified craftsman was so severely restricted. As many skilled men had joined the Forces, there were not enough to train apprentices and even those who remained were less willing to take time off to instruct young workers when piece-rates began to be introduced. At the same time, the higher wages that boys could get on unskilled or semi-skilled work, coupled with the knowledge that in any case their industrial training would be interrupted by the call-up at 18, lessened the readiness both of boys and their parents to undertake a long period of apprenticeship.

An enquiry into training for skilled trades made by the Ministry of Labour in the mid-twenties shows that in those occupations in which apprenticeship was supposed to be the rule, rather less than a quarter of all employers had in fact any apprentices to train. The proportion showed a wide variation from one trade to another, from shipbuilding at one extreme in which 88.5% had apprentices, to the brick and tile industry at the other with less than 8%. Printing with 62%, engineering and iron and steel with 53% and building with 36% come in the middle.

In engineering the proportion of apprentices to all male workers was 1 : 13.6 for firms of 600 employees or more, and 1 : 2.3 in those with less than five.

As the school-leaving age gradually went up, in the early years of the century, so did the age of entry into apprenticeship until by the mid-twenties 15½ - 16 was by far the most usual, and it seems as if for this reason and no other the period of apprenticeship has tended to fall slightly. For the period of

training was fixed not by the amount to be learnt (for it would be a remarkable coincidence if all crafts, however much they varied in nature, took exactly the same amount of time to master), but by Trade Union regulation. For some reason the age of 21 has always played a significant part in Union wage agreements and it was the insistence on the absolute necessity of paying a man of 21 the full adult rate for the job that fixed both the age of entry and the period of training. The seven-year training that had been usual was itself arbitrary and had been fixed partly by long-standing custom, and partly by the need to ensure that the apprenticeship ended at the age of legal majority when a boy might have the power to repudiate a contract made in his name if he wished to do so. As the school-leaving age was raised the period was reduced to five or six years so as to ensure that it still finished at 21, and unions were adamant that the age of entry should not be more than 16, in order to allow for a minimum of five years' apprenticeship before the age of 21 was reached.

It was the length of apprenticeship rather than the type of training given to which the Unions attached most importance. Some few firms had organised apprenticeship schemes with carefully systematised plans of training and had even in some cases established Works Schools; but the vast majority of apprentices learned their trade by being put under the charge of a skilled worker whose work they watched and to whom they acted as " mate ". In almost all cases the first few months or even the first year was largely wasted. The boy acted as messenger or " tea-boy " and what he learnt depended primarily on his own enthusiasm and keenness of observation.

Not all of this was completely useless, for it was necessary for the young worker to learn the layout of the factory and to become familiar with the names of the tools, materials and processes, but this could have been done in a very much shorter time if any care had been directed to introducing the boy to the job and giving him a few weeks of tuition. Much of the time was wasted because of the unwillingness of the worker under whom the apprentice was theoretically training, to lay off his own work in order to instruct a beginner. In some firms an extra payment was made to the adult to whom that apprentice was attached, to compensate him for the interruption in his own work, but even so, the benefit to the trainee depended partly on the variety of jobs that the skilled worker had to do and very much on his ability to impart his knowledge to somebody else. Most craftsmen are more skilled with their hands than with their tongues and it is only rarely that a man who is master of his trade has the imaginative insight to understand the difficulties and problems of somebody going newly to it; so that even where the adult worker took his job of instruction seriously, it was not always very well done.

The whole system was haphazard and casual and it was nobody's responsibility to ensure that the boy had the opportunity to learn the various branches of his trade nor that, even if he had the opportunity, he had, in fact, managed to reach a certain standard of competence. So long as he had put in the required number of years he was entitled to call himself a skilled worker and receive the appropriate rate of pay. Those who did not, in fact, receive a good all-round training or who had not the ability to profit from it, probably found it more difficult later on to get and to hold down a job; but this depended mainly on the demand for workers in their locality when they became adult.

The proportion of boys undergoing apprenticeship was, however, extremely small — only 13% of those under 21 in all industries. If we add to this number all those getting some form of training in manual work the proportion is still not very large — only 1 in 5 of youths under 21. The other 80% received no training at all but were employed in unskilled or semi-skilled operations. Of the 20% who were either apprentices or learners four-fifths were to be found in one small group of industries—shipbuilding, engineering and other metal industries, building, printing, wood-working and retail trade. But the vast majority of boys left school at 14 and took up whatever job happened to be available in the neighbourhood.

There was a great deal of disquiet about this situation amongst those whose work brought them into intimate contact with adolescence. But the tragedy of the period between the two Wars was that the immense shadow of chronic mass unemployment hung so black and menacing over the industrial scene as to blot out almost everything else. With so much adult unemployment in the basic industries and particularly in those such as shipbuilding, building and certain branches of engineering, in which as has been stated the largest amount of skilled work was to be found, little concern was felt about the flow of skilled workers for the future. It was not until the Second World War swept all adult labour into the Forces, or into essential industry, that the shortage of qualified men able to undertake jobs which required detailed knowledge and experience in handling precision tools began to force itself upon the attention. Skilled men were at a premium, and in many works the expansion of the repetition processes was held up because of the impossibility of getting hold of the nucleus of key workmen able to set and supervise the machines. The supply of men of such a type cannot however be rapidly increased, for it requires years of training, and whilst a certain amount could be done during the emergency to train people rapidly in certain branches of the work or to break down complicated jobs into their component processes, questions began to be asked about the future. Already early in the War it was realised that the end of hostilities would usher in a period of tremendous effort if industries were to recapture their export markets, and that this would be impossible without an adequate supply of trained workers. Unless the matter were taken in hand at once, these workers would not be forthcoming when they were most needed.

Let us now analyse a little of this background from the engineering point of view. What sort of engineer did we have in industry in the late thirties? The Planning Engineers, the Chief Draughtsmen and

Designers, the Toolroom Managers, the Machine Shop Superintendents, and so on — we have seen where practically all these came from and how nearly all started on the shop floor. We know they didn't have high-class instructors, and that they were left to fend and learn for themselves, but they had the one thing in common that money could not buy — practical experience. How proud they were of having started that way, and how good they were because of the years of practical experience they had had! These men were the nucleus of the production teams that served us so well in the Second World War.

How then can we take advantage from the lessons of history? Our Training Officers, and all who are connected with the training of apprentices, must be absolutely convinced of the utmost importance of practical training. Since the War the emphasis has been on technical training, even at one time to the near-exclusion of practical training, so that today we have draughtsmen in Drawing Offices on component and jig and tool design, and planning engineers in the Planning Office who are very good technically, having reached O.N.C. and H.N.C. level, but have had no practical experience worth talking about. The consequence of this is obvious. How can a draughtsman design a jig or fixture with any competence when he has never had the opportunity to make or even use one? The same handicap or disadvantage applies to the planner, production engineer and estimator, without this priceless experience.

the training workshop instructors and instruction

Most firms in Britain today realise the immense value of the apprentice training workshop, for here a boy can be kept under the critical eye of the various instructors. Instead of being pitched into the hustle and bustle of the machine shop he is put with boys of approximately his own age and educational standard. Here a syllabus is worked out, designed to teach him the uses, and how to use, hand tools and various machine tools. When one realises that a boy can get the same amount of practical tuition in one week as he would, say, on a City and Guilds course at a technical college, taking evening classes for one year, the value of the workshop speaks for itself.

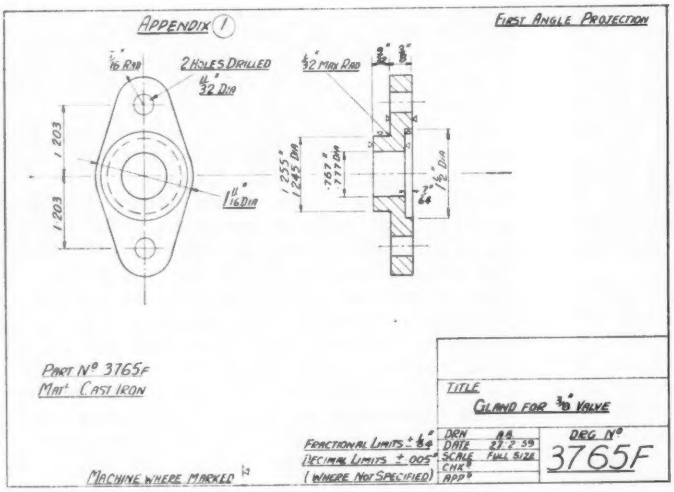
Unfortunately the small firm cannot afford the luxury of a training workshop. These firms will no doubt welcome the announcement by Mr. Heath, Minister of Labour, in March, 1960, of the Government plan for apprentice training. New facilities were being made for boys to spend their first year of their apprenticeship at Government Training Centres. Mr. Heath stressed that places would only be made available to boys accepted as apprentices by firms, with preference being given to boys from firms which are either unable to undertake apprentice training, or to increase their present number of apprentices. No charge will be made for the training provided, but employers taking part in the scheme would be required to give an undertaking to pay the wages of apprentices during the year, and to continue the boy's training afterwards, under the normal industrial arrangements. The usual provision for day-release would apply during the year. The first training places would be available early in the summer at eight Government Training Centres and he expected to set up classes at other centres later in the year; altogether some 300 training places would be provided.

Mr. Heath stated that the scheme had been approved as a whole by the British Employers' Confederation and the Trade Union Congress. The establishment of classes in engineering had been agreed by both employers and unions in the industry, and he proposed to extend the scheme to other trades. This announcement by the Minister will gladden the heart of everyone connected with the training of apprentices. Although there are some fine Group Apprentice Schemes, which have done and are still doing excellent work among the small firms, the scheme as announced by Mr. Heath was the move by the Government we had all been waiting for, for the more interest shown by the Government in apprentice training must increase the skill of our labour force to the ultimate benefit of our country.

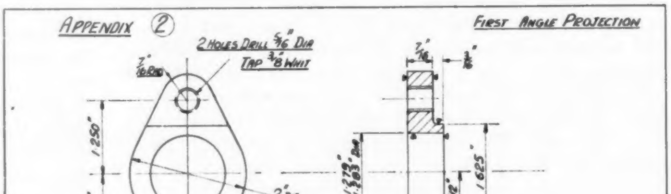
Apprentice training schemes have been described, and very aptly, as an investment for the future, and the training workshop is the department that absorbs most of the financial outlay. The management first of all must decide what end product they want from their training scheme. Are they looking for just machine operators for their own particular firm; do they want production engineers, planning engineers, designers and draughtsmen fitted out with the knowledge to suit just the particular product produced by them, or are they prepared to train youths for industry as a whole? The answer to these questions will determine the syllabus of training arrived at, the type of plant, etc., laid down in the workshop and the type of instructor that will be required. Type of plant is important, naturally, but the instructor and the quality of instruction given is one of the most important aspects of apprentice training. Apart from being expert in his own right, the prospective instructor should be taught the art of instruction. I use the word "art" with no reservations, for if every training workshop supervisor tells the truth this question of instruction to young people is most frightening. Even the presentation of facts has to be studied most carefully, for fear of misconstruction on the part of the apprentice.

It has been known for a boy, sitting on one side of a ciné camera, to have a totally different conception of the facts from a boy sitting on the other side, after watching a film on how to use a file. If we give this fact deep thought, it only proves how very important instruction in all its aspects must be treated.

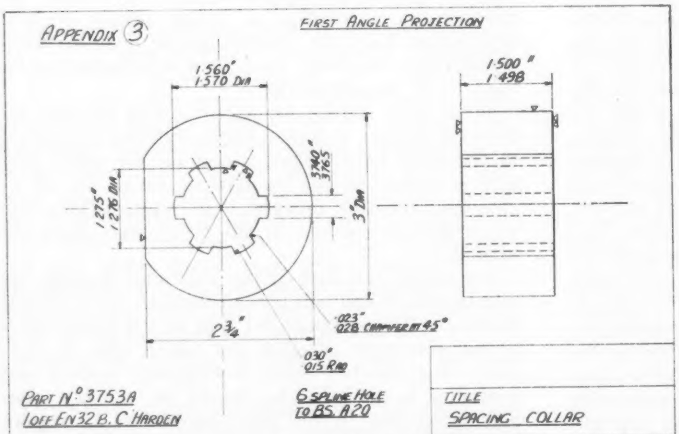
Let us try and look at the instructor through the pupil's eyes, if you will pardon the pun. Now, despite his funny clothes, remember that he has passed quite a comprehensive selection test which tells us right away that he has some intelligence, and if our instructor is not what he should be, the boy after looking at him in the first instance as an expert, begins to have doubts when he is told to do something, but not shown how to do it. As an illustration and to hark back to using a file, if the instructor



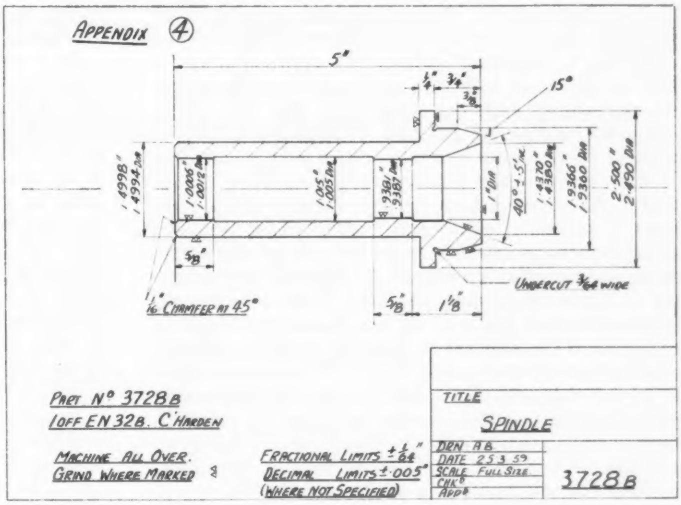
Appendix 1
Turning, boring and drilling



Appendix 2
Turning, drilling, tapping and milling



Appendix 3
Facing, boring, slotting or broaching, milling and surface grinding



Appendix 4
Turning, boring, heat treatment, internal and external grinding

cannot file flat then the boy begins to think it is impossible and the only way to obtain a flat surface is by using a machine. But if he sees a surface filed flat, really flat, then it is not an impossibility to him, and it will not be too long before he himself is filing flat. This is the way that most apprentices view every phase of their training, and to be good at his job an instructor has to be a good craftsman, with a flair for instructing, and have the patience of Job, as well as being a psychologist.

Fortunately there are many good courses available today to which the training officer can send his instructors. The Government Training Centre, Letchworth, to name but one, runs very good courses on Teaching Technique for craft instructors. Unfortunately it is not possible to send on instructors' courses, every employee the boy will have to come into contact with and sometimes some of the good work done in the training workshop is undone when the boy continues his practical training in the factory.

One of the main troubles for the slight lapse in the boy's conduct is mainly due to the supervisors of the departments having very little time to spend with the boy, or being unable to find him full employment. He may not have a machine to spare for one thing: it is no easy task for the supervisor to keep a boy fully occupied, unless the management have appreciated his position and have made provision for it. Idle time is the arch enemy of all apprentice training supervisors, for it is an established fact that when a boy has nothing to do he starts to learn bad habits. The supervisor knows this, and he is usually left with one alternative; he puts the boy with a craftsman to help and learn what he can. Here is where, through no fault of the craftsman, the high quality of instruction usually goes into a decline. This is one reason why, if it is possible the boy should be brought back into the training workshop for advanced instruction. With craft apprentices this is most essential.

setting of productionising problems

The productionising of components is a great mind-exerciser, and thought stimulative for all types of engineering apprentices, be they Production, Mechanical or Craft. A series of lectures-cum-discussions by the Chief Production Engineer leads the way to the setting of production engineering problems. These can be simple exercises building up from components requiring two or three operations, increasing in operations, in order to bring into use the various machine tools. For example, Appendix 1 to this Thesis shows turning, boring, and drilling operations. Appendix 2 shows turning, drilling, tapping, and milling operations. Appendix 3 shows facing, boring, slotting or broaching milling and surface grinding. Appendix 4 shows turning, boring, heat treatment, internal and external grinding.

Now it is obvious that similar exercises to these can be used more than once. For example, if we take Appendix 1 and, in the first instance, suggest that the total quantity required is six off P.A., then in the second instance 600 of P.A., and the third 600,000 P.A., then obviously we go right from the knife and fork method to a fully automatic means of production. These exercises should be a planned part of the training syllabus, getting harder and more complicated for the boys who will ultimately become production engineers. The Chief Production Engineer should always be consulted when these exercises are chosen. The analysing of the results of these exercises is most instructive and helpful to the Training Officer, especially in the early stages. They will point to possible weaknesses and lack of knowledge in the boy, which can be remedied by increased instruction or repetition of a subject.

the critical approach

The early introduction of a critical approach to a job is essential to the training of apprentices. The

aim to engender the engineering and probing mind should be high in the Training Officer's lists of musts.

During his practical training the apprentice learns how to use hand tools and machine tools; he knows the purpose of each one eventually, but it is surely wrong to teach him all these things parrot fashion without encouraging him to question why we do this or that. Let us teach him to query everything that is told him and everything he sees. Firstly, why do we need a particular component; what is the function of it; how important is it to the whole job; what degree of finish and accuracy is required to perform the function it is designed for? This is the kind of thought that leads to the modification of mating components to allow for the possible complete elimination of one of the mating parts. He must be taught to treat each and every job on its own particular merits and to use comparisons only as a guide. He should ask himself such questions as, is it possible to redesign the component to save machining operations, or even cut out machining altogether? Is this operation really necessary, if so, why do we do it this way, couldn't two or more operations be linked together? Is there a better machine we could use?

This question of encouraging the critical mind can be an embarrassment to the people on the shop floor who work alongside the apprentice, but most supervisors today are in close contact with the Apprentice Training Supervisor, and between them they usually manage to convince the man on the shop floor that the boy isn't cheeky, but that he had been told to ask, and keep on asking, until he is satisfied with the answers.

The critical approach is something that must be inbred in all good production engineers. Therefore an early start must be made to introduce it and a good time to start is in the early productionising lessons set for first-year apprentices.

cost consciousness

Allied with the early critical approach is cost consciousness, for it is of no use for a boy to learn to criticise and suggest different methods of production, unless he is conscious of the cost involved and whether or not the change would be justified financially.

The cost conscious problem should be a planned and carefully studied programme and should dovetail into the syllabus mapped out for the apprentice over his period of apprenticeship. According to the channel into which the apprentice is fed, so should the cost problem be planned to meet his required knowledge of the subject stage by stage. For instance, when the apprentice reaches a certain standard in his training, he could take part as a member of cost investigation teams.

Without getting complicated it is not too hard to prove to a boy that there are such things as "overheads". He must readily agree that such things as light, heating, water, gas and electricity must be paid for; the man who makes his wages up, the girl who brings the tea and the woman who cooks his canteen meal all have to be paid. Once he grasps the fact the less he is amazed when he is told the cost of such things as the small tools, etc., he uses in the training workshop.

It is very hard to put across to a boy the cost of materials, such as the various tool steels. If we write on a blackboard "High speed steel 3s. 6d. per lb.," etc., the boy may copy this information into his note book, but has it registered? It very seldom does! Now if we show him a cubic inch of steel and mark the price on it, then say a 2 in. cube and mark the price on that, let him handle them physically along with two others of identical size machined all over, with the price, plus overheads added, he is much more impressed. A few jigs and fixtures with the actual cost of manufacture marked on, broken down into cost of material, labour and overheads, tend to make him think more deeply into the cost when he gets a productionising problem. It is also a good idea to have a tentative list of overheads for each machine in the machine shop posted in some convenient spot in the training workshop and the cost of each machine tool in the training workshop could have the prices, (when new) displayed on it, in a prominent position.

These are but a few ways to impress upon a boy the importance of being "Cost Conscious".

the importance of providing a broader education

Non-technical education for apprentices is most essential for obvious reasons. Without a broader education the boy we have trained to be a first-class engineer will have damaging limitations. Therefore we must provide a balance to his education, teach the boy to think on a wider plane to enable him to speak clearly, logically, and with confidence, to provide in discussion a process of give and take. enabling him in later life to take his place in society as an equal number. Teach him the art of explaining to, and instructing other people. Get him on his feet during debates or discussions amongst his contemporaries, who are his biggest critics. Woe betide him if he is not sure of his facts — he soon gets shot down. The lesson from this very uncomfortable 10 minutes or so is obvious to him.

There are organisations who provide excellent instructors on non-technical subjects and character building courses — the Economic League Ltd. is one that readily springs to mind.

Let us not forget the value of works visits, where a boy can see apprentices of his own age working under different conditions. Let us teach the boy health forming habits — send him on Outward Bound or similar courses. These things make him self-reliant, breed tenacity, and makes him resourceful and altogether a much better engineer and citizen.

Most firms, during the 1920's, did not pay the full rate to an apprentice on completing his apprenticeship until he had served a term of improvership. This, in a lot of cases, induced him to leave and for reasons of financial gain some men during the next ten years or so of their careers had perhaps five or six, sometimes more, different jobs, sometimes moving to completely different industries.

We now know that this broadened their knowledge and made them better engineers. If we can then

(concluded on page 483)

Quarterly Newsletter to the Institution

reaming research

A research report has recently been issued on the effects of reaming conditions, reamer shape, cutting fluid and reamer wear on hole accuracy and surface finish when reaming low carbon steel.

In two previous researches PERA has investigated the influence of reaming conditions and reamer shape on the accuracy and surface finish of holes reamed in low carbon steel. In both investigations only a small number of holes was reamed under each set of test conditions to eliminate any effects due to wear of the reamer cutting edges. However, during the investigation covered by the latest report, a study was made of the effects of reamer wear under conditions similar to those used during the earlier investigations with the exception that a much larger number of holes was reamed, and the effects of using different cutting fluids were studied. The report contains a series of recommendations relating to three ranges of surface roughness values when reaming low carbon steel with standard straight flute or spiral flute reamers having a low helix angle. An empirical relationship was established between flank wear, cutting speed and the length of the cutting path; this relationship involves empirical constants which are dependent upon the tool material, workpiece material, reamer geometry, cutting fluid, hole dimensions, etc.

electrolytic machining

The difficulty of machining the new ultra-strength alloys economically has necessitated some radical changes in the approach to metalworking processes. Some of the most promising developments have occurred in the field of electrical machining, and the electrolytic machining process in particular seems to have great potentialities for machining ordinary and high strength alloys. In view of the increasing industrial interest in electrolytic machining, it has been decided that PERA shall carry out research in this field. Initially this research will be concentrated on contour forming operations such as cavity sinking, external contouring and hole forming rather than electrolytic grinding, which has already been the subject of considerable commercial development. Factors affecting machine design are now being studied and suitable equipment is being developed. A machine having a maximum power output of 1,500 amps at voltages between 6 and 15 volts d.c. will be constructed.

work study seminar

Many companies now recognise the considerable practical and financial advantages that can accrue from work study. Nevertheless, PERA's experience in this field has indicated that even where a work study unit is in operation, the full potential of the many different techniques involved is not always realised, and thus opportunities to cut production costs and improve product quality are frequently lost. A Seminar entitled "Making Work Study Pay" was therefore recently held at PERA for directors and senior executives from member-firms. The main purpose of the Seminar was to describe the various steps that can be taken to ensure that method study and work measurement yield the largest possible gains in productivity. The programme covered the aims of work study, the practical application of

During the past 18 months, PERA has been investigating the use of high explosives for metal forming. Metals which have already been formed by this technique include alloy steels, stainless steels, Nimonic alloys and non-ferrous alloys in thicknesses ranging from 0.16 in. to ½ in. The main advantages of explosive forming are low cost of tooling and the relatively simple equipment required compared with conventional metal forming processes. Work which has already been done by PERA has shown that the process has great possibilities, especially in the forming of relatively thick materials.

Materials Handling Group Discuss Town Planning

ONE of the most interesting meetings so far arranged by the Institution's Materials Handling Group Committee took place in Birmingham on 15th March last, when members of the City of Birmingham's Planning Department outlined the Corporation's plans for coping with their increasing problems of handling efficiently material, traffic and people.

The title of the discourse was "Town Planning for Freedom of Movement", and the speakers were **Mr. Leslie B. Ginsburg,** A.A.Dip., S. of P.Dip., A.R.I.B.A., A.M.T.P.I., Head of Birmingham's School of Planning; **Mr. N. P. Brand,** M.I.C.E., Engineer-in-Charge, Highways Section, Public Works Department, City of Birmingham; and **Mr. A. Geeson,** A.M.T.P.I., Principal Assistant Planning Officer, Town Planning and Redevelopment Section, Public Works Department, Birmingham. The Birmingham Section Chairman, Mr. J. Silver, M.I.Prod.E., presided over the meeting.

Mr. Geeson and Mr. Brand presented Birmingham's plans for future development and described how it was intended to deal with increasing volumes of goods, traffic and people into, through and out of the City. A typical development project was described and illustrated, showing the stages to completion from acquisition of the area, progressive demolition of existing buildings, and the rebuilding programme.

Ideas developed in main cities in other parts of the world were illustrated by Mr. Ginsburg, together with many ideas of his own, including pavements at first floor levels, and pedal cycles for business men.

Models, photographs and charts kindly loaned by the City of Birmingham, as well as models of buildings prepared by students of the School of Planning, were also on show, and contributed to the success of unusual and well-attended lecture.

The photograph shows one of the models being discussed by (left to right): Mr. F. E. Rattlidge, Immediate Past Chairman, Materials Handling Group Committee: Mr. A. Geeson; Mr. L. Ginsburg; Mr. J. Silver, Birmingham Section Chairman; and Mr. B. E. Stokes, Immediate Past Chairman, Editorial Committee of the Institution.

PERA NEWSLETTER — continued

method study and work measurement, and examples of the benefits achieved in industry. Consideration was also given to the organisation of work study activities, and a critical examination was made of the use of particular method study and work measurement techniques in various circumstances. Delegates were informed that results achieved in industry through PERA's work study activities include:

- annual saving of £20,000 in one department;
- production costs cut by three-quarters;
- number of scrapped parts greatly reduced — immediate saving of £2,500;
- five-fold increase in output;
- rate of production increased by one-third in three months;
- net annual saving of £5,600 in production of one part;
- production costs cut by 35%.

As some companies are not in a position to employ experienced and qualified work study specialists continuously, PERA has recently enlarged the staff providing members with direct assistance in all fields of work study. On request, PERA's work study engineers visit factories for two or three days to assess efficiency in all departments, and then recommend what further action is required. Normally, a preliminary survey is followed by a full investigation which reveals sources of inefficiency and leads to action to cut costs and raise output, often with little or no capital expenditure.

NEW BRITISH STANDARDS

Copies of the following British Standards, recently issued, may be obtained from the British Standards Institution, 2 Park Street, London, W.1, at the prices stated.

B.S. 1828 : 1961 Reference tables for copper v. constantan thermocouples. 6s.
B.S. 2972 : 1961 Methods of test for thermal insulating materials. 15s.
B.S. 2973 : 1961 Classification and methods of sampling and testing of insulating refractory bricks. 6s.
B.S. 3284 : 1961 Polythene pipe (type 710) for cold water services 6s.
B.S. 3366 : 1961 Dental cobalt chromium casting alloy. 3s.
B.S. 3376 : 1961 Open fire with convection with or without boiler. 4s. 6d.
B.S. 3377 : 1961 Back boilers for use with domestic solid fuel appliances. 3s.
B.S. 3378 : 1961 Domestic heating stoves using coke and other solid fuel. 5s.
B.S. 3381 : 1961 Metallic spiral wound gaskets for the petroleum and petrochemical industry. 5s.
B.S. 3382 : 1961 Electroplated coatings on threaded components. Part 1 Cadmium on steel components. Part 2 Zinc on steel components. 7s. 6d.
B.S. 3383 : 1961 Normal equal-loudness contours for pure tones and normal threshold of hearing under free-field listening conditions. 4s 6d.
B.S. 3384 : 1961 Dental gold solders. 3s.
B.S. 3385 : 1961 Direct reading personal dosemeters for X and gamma radiation. 3s.
B.S. 3456 : —— The testing and approval of domestic electrical appliances. Part A Heating and cooking appliances.
B.S. 3456 : 1961 Section A5. Electric toasters. 4s 6d. Section A.6 Electric coffee percolators. 4s. 6d. Section A7. Electric washboilers. 4s. 6d. Part B Motor-operated appliances. Section B3. Electric dry shavers. 4s.

NEW AIRCRAFT STANDARDS

B.S. G 178 : 1961 Crimped joints (non-insulated) for general purpose electrical cables for aircraft. 6s.

REVISED BRITISH STANDARDS

B.S. 131 : —— Methods for notched bar tests. Part 1 : 1961 The Izod impact test on metals. 6s.
B.S. 765 : 1961 Internal combustion engines, spark ignition type. 6s.
B.S. 1016 : —— Methods for the analysis and testing of coal and coke. B.S. 1016 Part 13 : 1961 Tests special to coke. 7s. 6d.
B.S. 2938 : 1961 Dental amalgam alloy (silver-tin). 3s.
B.S. 1928 : 1961 Gramophone records and reproducing equipment. 6s.

AMENDMENT SLIPS

Please order amendment slips by quoting the reference number (PD...) and not the B.S. number.
B.S. 529 : 1944/PD 4106; B.S. 537/PD 4154; B.S. 609/PD 4166; B.S. 665/PD 4156; B.S. 758 Part 2/PD 4139; B.S. 761/PD 4157; B.S. 825/PD 4134; B.S. 857/PD 4162; B.S. 887/PD 4137; B.S. 931/PD 4158; B.S. 1397/PD 4112; B.S. 1711/PD 4138; B.S. 1739/PD 4140; B.S. 1822/PD 4111; B.S. 1832/PD 4129; B.S. 2051 Part 3/PD 4122; B.S. 2655 Part 1/PD 4152; B.S. 2790/PD 5159; B.S. 3295/PD 4104 B.S. 3032/PD 4133; B.S. 3156/PD 4136; B.S. 3274/PD 4147.

STANDARDS WITHDRAWN

B.S. 13 : 1942 Structural steel for shipbuilding.
B.S. 366 : 1929 Round strand steel wire ropes for oil wells.
B.S. 1016 : 1942 Methods for analysis and testing of coal and coke.
B.S. 1326 : 1955 Domestic electric wash-boilers.
B.S. 2607 : 1955 Electric coffee percolators and brewers for domestic use.
B.S. 2608 : 1955 Electric toasters for domestic use.
B.S. 2991 : 1958 Electric dry shavers.

I.E.C. PUBLICATIONS

Publication I.E.C. 91 Recommended methods of measurement on receivers for frequency-modulation broadcast transmissions.
Publication I.E.C. 123 Recommendations for sound level meters.

"SOME ASPECTS OF APPRENTICE AND GENERAL TRAINING" — concluded from page 480

induce the boy to plan a period of "After Apprenticeship" designed to provide a wide and varied experience, by planned movement, our engineers and particularly our production engineers would benefit greatly and consequently the whole of industry would gain immensely.

conclusion

Technical training has received little or no mention in this Thesis, mainly because the work done by our technical colleges with their vast number of part-time teachers, who give two and three evenings a week in many cases, speaks for itself. The writer, having been one of these part-time teachers, cannot express too highly the praises of the entire staff of these colleges. When stressing the overall importance of practical training the "Technician" was uppermost in mind.

references

"Historical Background of Apprentices." *Recruitment to Skilled Trades* by Gertrude Williams.

"Government Plan for Apprentice Training." *Financial Times*, March, 1960.

THE PRINCIPAL OF

THE PRESIDENT

Mr. Harold Burke, who takes office as President for 1961/62, is a man with no time for half-measures. His decision to support a cause ensures his wholehearted co-operation and this characteristic has been displayed to the fullest extent since he joined The Institution of Production Engineers over 30 years ago. His work has aided to an inestimable degree the achievement of the Institution's present high standing and the expansion of its activities on an international scale, and he is perhaps best known to the membership as Chairman of the Special Committee on Reorganisation, 1951/52, which produced what has become widely known as "The Burke Report".

A Birmingham man, Mr. Burke is a prominent and popular figure in the Midlands, where he enjoys a well-deserved reputation for the successful exercise of industrial administration at all levels. He is a firm believer in the importance of good human relations in industry and practises this in his own organisation with excellent effect.

Educated at Birmingham College of Technology, Mr. Burke studied Economics, Industrial Organisation and Industrial Law at The University of Birmingham. He served his apprenticeship with Vickers, Ltd., and after holding appointments in several engineering firms, in 1947 he joined Elfson, Ltd., as Managing Director. When the Engineering Division of this Company was purchased by Concentric Manufacturing Company, Ltd., he accepted the appointment of Director and General Manager. He is now Deputy Chairman and Joint Managing Director of Concentric, Ltd; Chairman & Managing Director of Concentric (Engineering) Ltd; Chairman of Fletcher Bros. (Pressings) Ltd; and a Director of Concentric's other subsidiary Companies.

Following his election to membership of the Institution in 1932, Mr. Burke at once began to take an active part in the affairs of the Birmingham Section. For four years he was the extremely energetic Hon. Secretary and was subsequently elected Section President; he has served on the Section Committee for many years. He has been a Member of the Institution's Council since 1948, and has filled with distinction the offices of Chairman and Vice-Chairman. He has also served as Chairman of the Midlands Region of the Institution.

In addition to his industrial concerns and his unceasing work for the Institution, Mr. Burke has a wide range of interests and activities among the arts, in education and in social work. Among his principal hobbies are music and amateur operatics and dramatics. He is Chairman of the Manor Operatic Society; Chairman of Governors of Boldmere High School; Member of the Advisory Committee (Department of Industrial Administration) of The College of Advanced Technology, Birmingham; and Vice-President of the Infantile Paralysis Fellowship.

He is a member of The Institution of Mechanical Engineers; a member of the American Society of Automotive Engineers; and a Founder-Fellow of the British Institute of Management.

THE VICE-PRESIDENT

It is with great pleasure that the Council announce the election to the Vice-Presidency of Mr. R. Ratcliffe, C.B., M.B.E. Mr. Ratcliffe, who is Controller of the Royal Ordnance Factories, is a man of forthright opinions and progressive outlook and the Institution can look to him with confidence for leadership of a very high standard.

He has been a member of the Institution since 1948, and is a Past Chairman of the Education Committee.

OFFICERS, 1961-62

THE CHAIRMAN OF COUNCIL

Mr. R. H. S. Turner, M.A.(Cantab)., Director and Works Manager of Associated Electrical Industries (Manchester) Ltd., has been re-elected to a second term as Chairman of Council. Mr. Turner's first year of office has been marked by the outstanding wisdom and efficiency with which he has presided over the deliberations of the Council, and the particular attention he is devoting to the development of the Institution. Under his guidance, a Special Committee has been set up and has met regularly throughout the year, to consider the shaping of the Institution's policy in the near future.

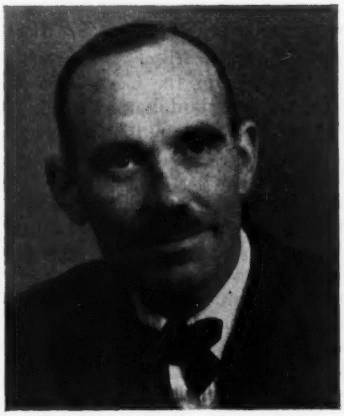
Mr. Turner's contributions to the success and development of the Institution in the North-West Region are well-known. He is Past President of the Manchester Section, a Past Regional Chairman, and serves currently on the Section and Regional Committees.

Educated at King's College School, Wimbledon, and St. John's College, Cambridge, Mr. Turner was a college apprentice at Metropolitan-Vickers Electrical Company Limited during 1930-32.

Following appointments in the Erection, Instrument and Meter, and Plant Departments, he became Superintendent of the Plant Department in 1948, and was appointed Assistant Works Manager, Main Works, Trafford Park, in 1952. In 1954, he became Works Manager, and was elected to the Board in 1955.

In addition to his Institution activities, he is a Member of Council of PERA, having previously served on the Association's Technical Policy and Metal Cutting Committees.

Mr. Turner is also a Governor of The Royal Technical College, Salford, and at the present time is a member of a Ministry of Education—U.K. Advisory Council Committee on Education for Management.



THE VICE-CHAIRMAN OF COUNCIL

Mr. A. L. Stuchbery, M.I.Mech.E., has been re-elected Vice-Chairman of Council. Mr. Stuchbery, who is Chief Technical Engineer of The Metal Box Company, Ltd., and a Past Chairman of the South Eastern Region of the Institution, was one of the earliest members of the Institution, having been elected in 1924.

He has a long record of continuous service to the Institution and it will give immense satisfaction to the membership that he has been able to accept re-election.

REPORT OF THE MEETING OF COUNCIL

27th April, 1961

THE fourth and final Council Meeting of the 1960-1961 Session was held at the Headquarters of the Institution at 10 Chesterfield Street, Mayfair, London, W.1, on Thursday, 27th April, 1961. The Chairman (Mr. R. H. S. Turner) presided over an attendance of 28 members. Also present, by invitation, were Mr. C. H. Hodgkins (Chairman of the Nottingham Section) and Mr. T. Young (Honorary Secretary of the Northern Region).

Before proceeding with the business of the meeting, the Chairman, on behalf of the Council, presented a silver tea service to Mr. Stanley Caselton, Deputy Secretary, on his 25th anniversary on the Institution's staff. With the presentation, said the Chairman, went the Council's appreciation of his loyal and efficient service, and their best wishes for another 25 happy years with the Institution.

After thanking the Council, Mr. Caselton asked the members to accept a new mahogany gavel and tablet for the Council table, to mark the occasion. In expressing appreciation of this gesture, the Chairman observed that the tablet bore the inscription *Dictum sapienti sat est* and hoped that future Chairmen of Council would bear this in mind.

Election of Principal Officers 1961 - 1962

On the motion of Mr. G. Ronald Pryor (President), seconded by Mr. H. W. Bowen, Mr. Harold Burke was unanimously elected President of the Institution for 1961 - 1962.

Mr. Burke said that this was one of the days in his life which he would always remember; he had been accorded the highest honour that the Institution could offer to any of its members. When he had been elected an Associate Member in 1932 (proposed by his good friend Percy Edwards who was present that day) his ambition had been to be on the Birmingham Section Committee and to serve as its Secretary. He had since held other positions in the Institution, but it had never occurred to him that he would eventually be offered the Presidency. He was very conscious of the responsibilities of the office, and of his own shortcomings, but Council could be assured that he would do his best.

Mr. Burke then moved the election of Mr. R. Ratcliffe, C.B., as Vice-President, 1961 - 1962. Mr. Ratcliffe, he said, had done valuable work both for the Institution and for industry. He was a man of forthright opinions who would give leadership of a very high standard. Mr. A. L. Stuchbery seconded the motion, which was carried unanimously.

Mr. Ratcliffe, in response, said he accepted the Vice-Presidency with a good deal of humility.

On the motion of the President (Mr. G. Ronald Pryor), seconded by Mr. Burke, and unanimously carried, Mr. R. H. S. Turner, whom Mr. Pryor described as "our very well-loved and efficient Chairman", was re-elected for a further term of office as Chairman of Council.

In expressing his appreciation of the honour, the Chairman said it was extremely difficult for anyone in an executive position to do as much work for the Institution as he would wish, and it was a matter of regret to him that he was unable to visit the Sections and Regions. In the forthcoming year he would do his best to meet as many members as possible.

The Chairman, in moving the election of Mr. A. L. Stuchbery as Vice-Chairman of Council for a further year, said he was particularly happy that Mr. Stuchbery, who was an invaluable member of the Institution, found it possible to undertake the duties of this post. The motion was carried unanimously, and Mr. Stuchbery, in reply, said that he was proud to serve the Institution in any way he could.

Finance

The Council adopted the statement of accounts as presented. The Chairman called attention to the fact that the excess of income over expenditure exceeded the budgeted amount, which indicated a healthy position. It seemed obvious that budgeting in the Regions and Sections was now a great deal more accurate than hitherto. There was also a most encouraging rise in subscription income.

Aircraft Production Conference, 1962

The Finance and General Purposes Committee reported that the programme for the Conference to be held at the College of Aeronautics, Cranfield, in April, 1962, had now been drawn up.

Secretary's Visit to Canada

The Secretary said that he was looking forward with great pleasure to his visit to Canada in May, and to addressing the National Productivity Conference organised by The American Society of Mechanical Engineers. The Canadian Section of the Institution was organising an entire section of the Conference.

The Secretary said he also hoped to call on The American Society of Mechanical Engineers in New York and on The American Society of Tool and

Manufacturing Engineers in Detroit. He would also visit Montreal, where the Institution had a number of members, to secure the appointment of at least a corresponding member, with a view to the eventual establishment of a Section.

Retirement of Registrar

The Secretary also reported the retirement, at the end of May, of Miss K. Allan, the Institution's Registrar, who had been on the staff for seven years. The Council recorded their appreciation of Miss Allan's services and conveyed to her their very best wishes for the future.

Mrs. J. Forrest, who has been Miss Allan's deputy, has been promoted to the position of Registrar.

Education

The Chairman of the Education Committee, Mr. W. G. Ainslie, reported a request from the National Council for Technical Awards to nominate a member to the Board of Engineering Studies, to fill the vacancy caused by the retirement of Sir Walter Puckey on the termination of his three-year period of office. It was unanimously agreed that Sir Walter should be re-nominated, coupled with a vote of thanks to him for the valuable work he had done during the past three years.

Successes for the last session for the Diploma of Technology in Production Engineering showed ten from the College of Advanced Technology, Birmingham, and seven from Loughborough College. The first award of the Sir Walter Puckey Prize was made by Sir Walter, supported by the President of the Institution, at the Welsh College on 10th March, 1961.

The Lord Austin Prize, 1960

The Council were pleased to adopt the recommendation of the Finance and General Purposes Committee that Mr. P. G. Varley, Grad.I.Prod.E., of the Rochester Section, be awarded The Lord Austin Prize for 1960 for his essay on "The Maintaining of Production Potential with shorter working hours by means of Advanced Management and Production Techniques".

The Chairman drew attention to the fact that this was the second time Mr. Varley had won the Lord Austin Prize.

Membership

The Council approved a number of applications for membership and transfer, details of which appear on pages 489 - 490.

The Journal

It was reported by the Secretary that a new advertising contract had been signed with the Institution's Agents. The terms of the new contract, which had been negotiated by the Chairman of the Editorial Committee, Mr. John M. Brice, would safeguard against possible loss incurred as a result of the steady increase in membership and, consequently, the number of Journals printed. The Chairman said that Mr. Brice and his Committee were to be congratulated on the arrangement, which could save the Institution a considerable amount of money a year if applied in full.

Publication of Research Papers

It was reported by the Editorial Committee that agreement had been reached on the format and style of the new research quarterly, which it was hoped to launch towards the end of 1961. Professor N. A. Dudley, of the University of Birmingham, who had accepted the Institution's invitation to be Honorary Editor of the publication, was at present assembling his panel of Consulting Editors and gathering material for the first issue.

Institution Papers

The Council were advised by the Papers Committee that one Named Paper remained to be presented during the quarter. This would be The 1961 Viscount Nuffield Paper, which would be given at the University of Bristol on 14th June, by Sir Willis Jackson, Director of Research and Education, A.E.I. (Manchester) Ltd. The subject chosen was: "Some Human Aspects of Engineering Progress".

The 1960 George Bray Memorial Lecture, which was presented at Olympia on 26th April, 1961, by Mr. H. Silman, on "The Protective Treatment of Metals Against Corrosion", appears in the July issue of *The Production Engineer*.

National Conference, 1962

It was reported by the Papers Committee that preliminary arrangements had been made to hold a two-day meeting in London, in May, 1962, on the theme: "Design for Automated Production (Product, Tool and Method)". The co-operation of all Sections of the Institution had been enlisted in obtaining a selection of Papers for presentation at this meeting.

Research

The following reports were received from the Research and Technical Committee:

Materials Handling Group

The Group Committee is concentrating its efforts on the planning of a one-day Convention in London, in November, 1961, on the theme "Profit by Handling".

The London Materials Handling Section held its first general meeting in February last, providing an opportunity for members to meet informally. This Section also arranged a most successful visit to the E.M.I. Record Factory at Hayes on 2nd March.

The Birmingham Materials Handling Section held a lecture evening on 15th March, in collaboration with the Corporation of Birmingham, when a most interesting address was given on "Town Planning for Freedom of Movement" (see page 482).

The Group continues to participate in the Study Groups set up by the National Joint Committee on Materials Handling. The Chairmanship of the Group Committee has now passed to Mr. H. Bond, following

the resignation of Mr. A. E. Dupree in consequence of pressure of work following a new appointment.

Computers and Production Control

All the case studies required for the report have now been received and the Sub-Committee is finalising the report.

Control of Quality

As a result of representations by this Sub-Committee, the British Productivity Council has called a meeting of all organisations and Government Departments interested in quality control, to discuss the co-ordination of activities in this field. It is hoped that as a result of this meeting a national joint council may be set up.

The Sub-Committee feel that the greatest need at present is for propaganda on quality control, and they are planning a further series of articles for the Journal. A booklet explaining quality control in basic terms is also being drafted.

Co-ordination of Production Management Techniques

The members of the Sub-Committee continue their work on the draft report.

Standardisation

It was reported by the Standards Committee that work which originated from this Committee on the standardisation of unit heads has resulted in the issuing of a new British Standard (B.S. 3295 : 1960) for the slide type of unit head, and that this document will form the basis of discussions in the International Organisation for Standardisation.

The Sub-Committee continue to discuss the inch/metric problem and a statement has been prepared by the Chairman for general publication.

A recommended list of text books on the fundamental principles of standards is being drawn up for students.

The Joint I.Prod.E./B.S.I. Standing Advisory Committee on the Use of Standards in Industry had met twice during the quarter to discuss the arrangements for the 8th Standards Conference to be held in London in May, 1961.

The Library

It was reported by the Library Committee that the Supplement to the Library Catalogue should be ready within a few weeks.

Work on the history of the manufacture of the small electric motor was going forward, and the Committee would be most grateful to hear from any member in a position to assist in this project.

Region and Section Reports

The Council received a number of Regional and Section reports. The Chairman commented that the standard of the reports received continued to improve. For the past year the proposal that Sections should report to their Region quarterly, and Regions to the Council annually, had been under consideration, and a report on the views expressed was now being compiled, to place before the next meeting of Council.

Liaison with Overseas Sections

The Vice-Chairman of Council (Mr. A. L. Stuchbery) reported that among the visitors to Headquarters during the quarter had been Mr. Ian McLennan, Chief General Manager of The Broken Hill Proprietary Company, Ltd., and the newly-elected President of the Australian Council, with whom some interesting and useful conversations had taken place.

Other welcome visitors were Mr. T. Mudie, of the Melbourne Section; Professor Wright, of Trinity College, Dublin; and Mr. B. N. Ganguly, of the Calcutta Section.

Some valuable suggestions and comments had been received from a number of Sections outside the U.K. concerning the President's Memorandum on Policy, and these had been placed before the Special Committee.

Obituary

The deaths of the following members were recorded with deep regret:

Members: V. S. Bowman; W. Clegg; J. W. Codwell; J. J. Gleeson; J. Hargrove; R. Hunter; A. White; R. Kirchner; E. Mallalieu.

Associate Members: H. Brook; W. J. Godwin; J. C. W. Hall; F. W. Moore; J. L. Stevenson.

Graduates: J. M. Aubrey; C. P. Hogate; G. Kuruvila.

Date and Place of Next Meeting

It was agreed that the next meeting of the Council should take place on Thursday, 27th July, 1961, at 11 a.m., at the Headquarters of the Institution, 10 Chesterfield Street, Mayfair, London, W.1.

ELECTIONS AND TRANSFERS

27th April, 1961

ADELAIDE SECTION
As Member
G. Trotter.

BIRMINGHAM SECTION
As Associate Members
G. B. Booth; E. V. Cole.
As Associate
R. W. Thomas.
As Graduates
B. P. Smith; S. G. S. Marris; C. J. Jackson; B. Chapman; D. E. Callow; T. N. F. Crick; K. P. Jagota; P. Tranter; C. C. Gallagher; D. T. Pangbourne; P. D. Bellingham.
As Students
G. D. Moll; R. N. Paul; N. S. Knight; C. H. Whittaker.
Transfers
From Graduates to Associate Members
L. A. Hoefkens; D. W. Edwards; R. V. W. Forsyth; P. R. Bergson; J. P. Seward; P. Fineman; J. W. E. Walker; R. G. F. Lowe.
From Students to Graduates
B. A. Jackson; W. K. Luk; R. B. Clark; M. L. Turner.

BOMBAY SECTION
As Graduate
N. C. Sukharamwala.

CALCUTTA SECTION
As Associate Member
G. M. Bhattacharyya.
As Student
P. N. Gupta
Transfers
From Associate Member to Member
P. J. O'Leary.
From Student to Graduate
S. S. Gogia.

CANADA SECTION
As Students
D. M. Cowan; W. A. Grundman; R. E. Carter; H. A. Hill (Article 19).
Transfers
From Graduates to Associate Members
A. M. Hand; J C. R. Nicholson.

CARDIFF SECTION
As Associate Members
P. D. McGough; R. H. Matthews.
As Graduates
P. Williams; A. P. Cox.
As Students
G. B. Evans; T. J. Grayson; A. J. Brown; W. M. Gooding; A. H. M. John.
Transfers
From Graduate to Associate Member
R. Beddoe.
From Students to Graduates
G. G. Hitchings; A. Williams.

CORNWALL SECTION
As Members
G. C. Lee; K. Farnell.

COVENTRY SECTION
As Members
R. S. Miles; C. H. Kirby.
As Associate Member
A. V. Manning.
As Graduates
N. C. Shannon; D. Harrison; B. W. Jeacock; D. E. Bromwich.
As Students
P. N. Hancock; D. W. Cooke; J. N. Cambray.
Transfers
From Associate Members to Members
C. V. Clarke; J. H. Cribb.
From Graduates to Associate Members
W. Staniaszek; K. W. Metcalfe; B. F. Willetts.
From Students to Graduates
C. K. Clark; J. A. Wood.

DERBY SECTION
As Graduates
T. H. Emery; F. Dawson; A. A. Hinchcliffe; F. D. Redshaw, A. Whitehurst.
As Student
I. McB. Clay.
Transfer
From Graduate to Associate Member
H. C. Hartshorne.

DONCASTER SECTION
Transfer
From Graduate to Associate Member
T. Sanders.

DUNDEE SECTION
As Students
A G. Reilly; D. McN. Mitchell.
Transfer
From Graduate to Associate Member
I. R. H. Beattie.

EDINBURGH SECTION
Transfer
From Graduate to Associate Member
J. L. Bland.

GLASGOW SECTION
As Associate Member
R. W. Murchie.
As Graduates
J. J. Milne; S. B. Beaumont; A. W. Tinto; R. Kerr.
Transfers
From Graduate to Associate Member
G. M. Hayden.
From Student to Graduate
C. S. Murray.

GLOUCESTER SECTION
As Graduates
J. A. Williams, H. V. Grainger.

HALIFAX & HUDDERSFIELD SECTION
As Associate Member
K. C. Edwards.
As Graduate
D. Woolley.
Transfer
From Associate Member to Member
H. Stansfield.

IPSWICH & COLCHESTER SECTION
As Associate Member
E. Mlynarski
As Student
A. R. Searle.
Transfers
From Associate Members to Members
F A. Clements; R. V. Taylor; R. P. Brown.

LEEDS SECTION
As Associate Member
D. E. Raine.
As Graduates
M. Child; G. Hunter; J. Harvey.
As Students
M. H. Walker; H. Pretty.
Transfers
From Associate Member to Member
G. Ramsden.
From Graduates to Associate Members
F. Cawood; H. Handley.

LEICESTER SECTION
As Graduates
G. R. Slater; G. Town.
As Students
B. Narain; J. D. Bielby; W. M. Pearson; B. M. Tipping.
From Associate Member to Member
G. S. Cope.
Transfers
From Graduates to Associate Members
C. R. Hewitt; E. G. Davis.

LINCOLN SECTION
As Associate Members
W. R. Collier; A. Sutherland.
As Student
W. S. R. Parry.

LIVERPOOL SECTION
As Graduate
M. Leedham.
As Students
E. Mason; D. Atherton.
Transfers
From Graduate to Associate Member
R. Morris.
From Student to Graduate
P. H. Starkey.

LONDON SECTION
As Member
K. Trickett.
As Associate Members
D. G. White; C. P. Turner; R. I. Hall; R. G. N. Hall; K. J. Bidston; H. Sanders.
As Graduates
K. K. P. Lam; J. E. Hunt; J. L. Milton; H. K. Yung; M. E. Hodges; K. G. Eade; W. C. Baird; A. Bunting; A. W. Maitland; P. G. Hearne; I. K. Partington; W. Bloodworth; A. L. Beastall.
As Students
D. E. Alleway; J. W. R. Chandler; P. J. Crawford; A. D. Eales; D. C. Evans; J. H. Saunders; R. S. Pratt; K. S. Elvery; E. H. H. Hiblen; G. Birchmore; J. G. Singh; M. T. W. Toulson; A. E. R. Grubb; M. H. Press; M. Williams; M. A. Popper; R. A. Rumens.
Transfers
From Graduates to Associate Members
R. J. Cattle; J. H. Ede; R. Iredale; P. G. Fearfield; A. Aziz; S. A. Petch L. R. Rust; R. E. Thompson; L. Strauss; G. D. Evans; K. C. Gamston.
From Students to Graduates
T. I. V. Blayney-Simpson; R. E. Hogben; J. B. Tuttle; W. G. Winder; B. R. Mills; L. A. Gaskin.

LUTON SECTION
As Graduates:
G. B. Horsler; P. R. Stephens; M. F. Hall; J. E. Samuel.
As Students
O. C. Smith; C. D. Firth; A. C. Tyler; W. B. Easton; M. Sharratt; P. Reilly.
Transfers
From Graduates to Associate Members
J. B. Gooderson; J. F. W. Walker; H. E. Coelho.
From Graduate to Associate
L. D. Mathews.
From Students to Graduates
N. G. Fletcher; B. A. Hammond; G. J. Hill; P. E. Prosser; D. J. McLeod.

MANCHESTER SECTION
As Graduates
B. Greenhalgh; S. Corbett; C. Slowe; D. W. T. Hague; H. C. Jindal; M. J. Pennington; N. A. Ellison.
As Student
D. J. Ellis.
Transfers
From Associate Members to Members
Z. Funt; D. I. MacDonnell.
From Graduate to Associate Member
W. Hickling.
From Students to Graduates
N. Rose; R. H. Thornley.

MELBOURNE SECTION
As Graduates
F. R. Bristow; B. E. Butt; J. D. Edwards.
As Students
K. W. Hall (Article 19); R. J. Wallace; A. R. Membrey; K. K. Cheung; D. F. Leigh (Article 19); R. B. Hodges.
Transfer
From Graduate to Associate Member
E. K. Stephenson.

NEWCASTLE UPON TYNE SECTION
As Graduates
M. Holland; A. A. Kussad.
As Students
K. Armstrong; A. Howe; D. J. Lane; F. W. Hadfield; J. Maughan.
Transfer
From Student to Graduate
R. Lamb.

NOTTINGHAM SECTION
As Member
S. V. Herrod.
As Graduate
R. Leivers.
As Students
T. A. Weaver; A. G. Gimson; K. C. Evans.

NEW ZEALAND SECTION
As Associate
A. J. Smaill.

NORTHERN IRELAND SECTION
As Associate Member
D. H. Abbott.

Transfer
From Graduate to Associate Member
F. D. Duffin.

OXFORD SECTION
As Associate Member
D. Jones.
As Graduates
F. P. Brough; B. R. Biggs.
Transfer
From Students to Graduates
F. Mikaati; I. L. Slade.

PETERBOROUGH SECTION
As Student
J. C. McCahill.
Transfer
From Graduate to Associate Member
G. R. Ridgway.

PRESTON SECTION
As Graduates
A. K. Potdar; P. Thompson; A. Hornby; W. J. White; I. Slater.
As Students
N. McKeand; W. M. Roberts.

ROCHESTER SECTION
As Graduate
K. G. Hillman.
As Student
J. D. Norris.
Transfers
From Graduates to Associate Members
J. R. Anderson; D. R. Lawson.
From Students to Graduates
M. J. Lucas; S. R. Croucher; P. D. Clayton.

SHEFFIELD SECTION
As Member
J. F. Ross.
As Associate Members
L. J. Ford; H. J. Roake.
As Associate
E. W. Lofts.
Transfers
From Graduate to Associate Member
S. G. Pardy.
From Students to Graduates
J. Almond; J. A. Idell; P. J. Wilson; B. D. Steel.

SHREWSBURY SECTION
As Associate Member
A. T. G. Lee.
As Graduate
F. J. Howells.
As Students
N. Wagstaff; J. M. Dovey.

STOKE-ON-TRENT SECTION
As Graduate
G. K. Darke.
As Student
G. T. Salvage.
Transfer
From Graduate to Associate Member
R. J. Spencer.

SOUTH AFRICA SECTION
As Members
M. E. Walsh; A. E. Marx; J. Astrup; J. C. Proudfoot.
As Associate
J. A. Cook.

SOUTH ESSEX SECTION
As Graduates
C. W. Foot; D. Clarke; A. P. Bond; T. E. Chapman; W. A. T. White; J. A. Poole; L. E. Helsby.
As Student
A. A. Butcher.
Transfers
From Students to Graduates
R. A. Cook; J. A. Cottrell.

SOUTHAMPTON SECTION
As Member
P. F. Rogers.
As Graduates
J. A. Yates; A. Hind; J. B. Hooton; A. Wilson; D. C. Harrison; M. H. Rawlings.
As Student
R. J. T. Wood.
Transfers
From Associate Member to Member
L. J. Service.
From Graduate to Associate Member
P. J. Orrick.

SWANSEA SECTION
As Graduate
F. E. D. Mitchell.
Transfer
From Graduate to Associate Member
B. D. O. Edwards.

SYDNEY SECTION
As Graduate
R. K. Hackney.
As Students
B. G. Jones; L. J. Manning.
Transfer
From Student to Graduate
W. M. Ward.

TEES-SIDE SECTION
As Associate Member
C. Smith.
Transfer
From Student to Graduate
A. Wright.

WESTERN SECTION
As Graduates
J. Greatrex; M. R. Bedingfield.
As Students
R. G. Stone; R. T. Webster; R. Evans; J. A. Price.
Transfers
From Graduates to Associate Members
J. D. Collins; P. F. Jowitt.
From Student to Graduate
K. M. Charlton.

WOLVERHAMPTON SECTION
As Members
J. O. Robinson; R. Clueit.
As Associate Member
E. R. Argue.
As Graduates
H. J. Richards; R. A. Besant; D. B. Legge; T. E. Dulson; T. D. Ford; N. E. Nicklin; C. F. Devison; D. Stone.
As Student
T. E. Beedle.
Transfer
From Associate Members to Members
H. Matthews; L. Smith.
From Graduates to Associate Members
K. Knott; T. R. Blewitt.
From Student to Graduate
B. M. Cooper.

WORCESTER SECTION
As Student
A. D. Truman.
Transfers
From Associate Member to Member
W. F. Marshall.
From Graduates to Associate Members
A. G. Waters; D. H. Greenhill.

NO SECTION
As Member
W. C. Coulton.
As Associate
N. R. Lewis.
As Graduate
B. Halman.
Transfers
From Graduates to Associate Members
L. G. Landrock; L. W. Midgley.
From Student to Graduate
N. R. Robinson.

FULL-TIME COURSE ON STATISTICAL QUALITY CONTROL

THE COLLEGE OF ADVANCED TECHNOLOGY, Birmingham, is again offering a full-time course of three weeks' duration on "Statistical Quality Control and Acceptance Sampling", commencing Monday, 11th September, 1961.

The course is primarily intended as an introduction to the subject. Nevertheless it provides the basic training necessary for Quality Control Engineers. The first fortnight will be spent in covering the general principles and procedures of quality control. The final week will be devoted to lectures by specialists from industry, and to visiting the works of firms employing quality control, where members of the course will be able to see the practical application of quality control methods, and discuss the techniques and associated problems.

The course will be directed by Mr. J. D. Morrison, Principal Lecturer in Metrology and Quality in the Production Engineering Department, and will be run in co-operation with the Mathematics Department.

Further details and application forms can be obtained from the Bursar, College of Advanced Technology, Gosta Green, Birmingham, 4.

CANADIAN PRODUCTION CONFERENCE

A display panel of information on the Institution's aims and objects, together with copies of recent publications, was a feature of the Conference organised by the Production Engineering Division of the Ontario Section of The American Society of Mechanical Engineers, and held in Toronto last May.

Photographed here with the Panel, which was organised by the Institution's Canadian Section, are Mr. S. Carroll, M.I.Prod.E. (left), Chairman of the Section, and Mr. Selwyn Pritchard, M.I.Prod.E., Past Chairman.

Mr. W. F. S. Woodford, Institution Secretary, who attended the Conference, also gave one of the theme addresses on "International Productivity Co-operation in the Future," which appeared in the June issue of "The Production Engineer."

HALIFAX-HUDDERSFIELD DINNER

The annual dinner of the Halifax & Huddersfield Section, held at the White Swan Hotel, Halifax on 7th April last, was a well-attended and enjoyable function. Among the guests were the President of the Institution, Mr. G. Ronald Pryor, and Mr. G. M. Butler, Joint Managing Director of the Butler Machine Tool Company, Ltd., Halifax. The Section Chairman, Mr. R. W. Asquith, presided and Mr. H. Crompton, Regional Chairman, replied to the toast of "Our Guests."

In the group above are (from left): Mr. Pryor; Mrs. G. M. Butler; Mr. R. W. Asquith; Mrs. Asquith; and Mr. G. M. Butler.

APPOINTMENT OF ASSISTANT EDUCATION AND TECHNICAL OFFICER

Mr. W. S. Horwood has been appointed the Institution's Assistant Education & Technical Officer, replacing Mr. I. B. King who recently returned to industry.

Mr. W. S Horwood

Mr. Horwood, who comes from Australia, holds a Bachelor's Degree in Industrial Engineering of the University of New South Wales. After completing his apprenticeship he obtained industrial experience in Australia in various capacities, including that of Methods-Time-Motion Analyst; Estimating Draughtsman (Electrical); Operations Research Engineer; and Supervising Production Planner and Controller.

Obituary

F. W. Cranmer, M.I.Prod.E.

BY the death of Frank Cranmer, the Institution has lost one of its earliest members and certainly one of its most staunch and loyal workers. Indeed, his record of service over a period of 30 years in the North-West can only be truly assessed by those who knew and worked with him, for he never sought the limelight. As Secretary of the Manchester Section from 1934 - 1950, and then successively Section Chairman, North-West Regional Chairman, Member of Council and of the Membership and Educational Committees, he worked tirelessly in his main interest — membership matters.

Frank Cranmer was a personality. He was an authority and a stickler on correct procedure in Committee and left no point uncovered. He was a champion of the Ordinary Member and if he thought occasion demanded, he was a fearless critic of the Establishment either verbally or by letter. In addition to his I.Prod.E. work, he was a Member of Manchester Productivity Committee and a Life Member of the Manchester Association of Engineers.

No mean sportsman, he carried something of the zest and bonhomie of the playing field into his business and social life. In his youth he played hockey for his native county of Warwickshire and also for Northumberland and he played club cricket until well into middle life. He was a member of Ringway G.C. and a Vice-President of Bowdon C.C. and when his own playing days were over, he organised a Junior Section and coached and encouraged the young and aspiring.

For a period of 25 years he was my colleague in Institution matters and my respected rival in business.

Always keenly interested in educational matters, he was a Governor of Openshaw Technical College, a Member of the Engineering Advisory Committee of the Union of Lancashire and Cheshire Institutes and our own representative on the Court of Manchester College of Science and Technology.

Truly he lived the full life — who

"*Comprehended his trust and to the same*
Kept faithful with a singleness of aim."

H. SPENCER SMITH.

Dr. E. L. Diamond

IT was with deep regret that the Institution learned of the sudden death of Dr. E. L. Diamond on May 22nd at the comparatively early age of 59.

He was educated at King's College, London and held the degrees of Master of Science and Doctor of Philosophy. In 1922 he joined the Midland Railway as a pupil of Sir Henry Fowler and was later, for a number of years, on the staff of The Institution of Mechanical Engineers. After service with the Inspectorate of Fighting Vehicles during the Second World War, he joined the British Iron & Steel Research Association, where he served as a Principal Scientific Officer. He went to The British Standards Institution in March 1949, as Head of the Mechanical Engineering Section and, following the reorganisation in 1955, he became a Divisional Chief Technical Officer.

Ernest Leontine Diamond will be remembered in the Institution chiefly for his work with the Standards Committee, on which he had represented the British Standards Institution since 1951. He was a man with a high standard of values and, although essentially patient and tolerant, was often impatient of trivial discussion and had been known to express himself forcefully when asked to undertake tasks which he felt to be of little moment. He established a relationship between the Institution and The British Standards Institution which was of inestimable advantage to both.

To his widow and three sons the Institution offers its deepest sympathy.

H. STAFFORD
Chairman, Institution's Standards Committee.

DIARY FOR 1961-1962

1961

AUGUST 29 - SEPTEMBER 1 **Summer School, Cranfield** (see Journal Supplement)

OCTOBER 17 ... ... **The 1961 Sir Alfred Herbert Paper, London.**
Speaker: **Mr. David Donne,** Charterhouse Industrial Development Co.
Subject: **"Finance in Industry"**

NOVEMBER 1 ... ... **Annual Dinner, Dorchester Hotel, London.**
Principal Guest: **The Rt. Hon. the Viscount Chandos, P.C., D.S.O., M.C.**

NOVEMBER 3-4 ... ... **Materials Handling Convention, London.**
Theme: **"Profit by Handling"**

1962

APRIL 5-7 ... ... **Aircraft Production Conference, College of Aeronautics, Cranfield.**
Theme : **"Building Aircraft for the Competitive World Market"**

NEWS OF MEMBERS

Mr. A. E. Clifford, Member, formerly with the David Brown Group and with Crittall Luxfer Ltd., recently joined Armstrong, Stevens & Son Ltd., of Willenhall and Birmingham, and has now been appointed Joint Managing Director. He is a Past Chairman of the Halifax and Huddersfield Section, and was a member of the East and West Ridings Regional Committee, and Nottingham Section Committee. He now serves on the Wolverhampton Section Committee. He has also served on the Council of the Institution.

Mr. F. B. Coombes, Member, Chief Designer of compressors, hoists and pneumatic tools for Holman Brothers Ltd. since 1952, has been appointed General Manager of Holman's subsidiary company, Maxam Power Ltd. Mr. Coombes, who has been with Holman Bros. for 32 years, is Chairman of the Institution's Cornwall Section.

Mr. G. M. Hayward, Member, Technical Director of F. J. Edwards Ltd., London, has been appointed Joint Managing Director of Chard Machinery Manufacturing Co. Ltd., Chard, their subsidiary Company.

Dr. F. Koenigsberger, Member, has been appointed Professor of Machine Tool Engineering at the Manchester College of Science and Technology, University of Manchester.

Mr. J. Milwain, Member, has retired from his position at George Angus & Co. Ltd. (Gear Division). He was Chief Inspector for four years and latterly Works Manager. He served an indentured apprenticeship at Rolls-Royce Ltd. He was Chief Inspector at David Brown & Sons Ltd., Huddersfield, for 20 years, and subsequently Assistant Production Manager in charge of light and heavy engineering departments. During this time he spent six months at the Company's factory in South Africa. He has served on both the Yorkshire and Halifax Section Committees and is a Past President of the Halifax Section.

Mr. J. R. Roberts, Member, has been appointed Head of the Production Engineering Department at the Stretford Technical College. He was formerly Senior Lecturer at the College of Technology, Bristol.

Mr. C. W. J. Downs, Associate Member, has relinquished his appointment as Assistant Lecturer at Farnborough Technical College and has now taken up an appointment as Editorial Assistant on the staff of *Machinery Lloyd.*

Mr. A. Gilmore, Associate Member, has been appointed Works Manager of the Wakefield factory of British Ropes Ltd.

Mr. W. R. Jones, Associate Member, has taken up an appointment in the Production Engineering Department of the College of Technology, Swansea. He was formerly with the Gorseinon College of Further Education.

Mr. S. D. Malhotra, Associate Member, has been transferred from Calcutta to take up the position of Officer-in-Charge, Ordnance Factory, Bhusawal.

Mr. G. H. Newton, Associate Member, has been appointed Works Manager, Meter, Relay and Instrument Division of the English Electric Co. Ltd., Stafford.

Mr. S. Parnell, Associate Member, has been appointed Deputy to the Chief Engineer of the Holman Group of Companies.

Mr. S. A. Petch, Associate Member, formerly Production Superintendent of M.O. Valve Co. Ltd., has now taken up an appointment as a Senior Methods Engineer with Morphy-Richards (Cray) Ltd.

Mr. D. Priestley, B.Sc., Associate Member, has been appointed Senior Lecturer in the Department of Mechanical Engineering at the Stafford College of Technology. He was formerly Lecturer in Mechanical and Production Engineering at Hatfield Technical College.

Mr. M. E. Rosner, B.Sc.(Eng.), Associate Member, has relinquished his position as Senior Lecturer in Mechanical Engineering at Hendon Technical College, and has taken up an appointment as Head of the Mechanical and Production Engineering Department of the Mid-Essex Technical College at Chelmsford.

Mr. F. B. G. Sammons, Associate Member, formerly Technical Sales Representative in Yorkshire and Lancashire for The Moore Manufacturing Co. Ltd., Bradford, has been appointed Sales Manager.

Mr. L. J. Saunders, Associate Member, formerly Unit Manager, Stock Products Organisation, Glacier Metal Co. Ltd., has taken up a position as Works Manager at Celotex Ltd., London.

Mr. M. J. Silver, B.Sc.(Hons.), Associate Member, formerly Assistant Works Manager of the Mostradio Works, of Radio & Allied Industries Ltd., is now a Divisional Controller with Associated Automation Ltd. (Elliot-Automation Ltd.), London.

Mr. D. R. Smith, Associate Member, has recently relinquished his position as Manager with the Michelin Tyre Co. and has taken up an appointment as Chief Works Engineer of the Burton-on-Trent factories of B.T.R. Industries Ltd. Mr. Smith was an active member of the Stoke-on-Trent Section.

Mr. G. Smith, B.Sc.(Eng.), Associate Member, will be taking up, on the 1st September, the post of Senior Lecturer in the Department of Aeronautical and Mechanical Engineering at the College of Science and Technology, Bristol. He is at present a Lecturer in the Mechanical, Civil and Production Engineering Department at the Harris College, Preston.

Mr. J. R. Thompson, Associate Member, has taken up an appointment as a Sales Engineer with Rockwell Machine Tool Co. Ltd. in the Midlands area. He was formerly with The Churchill Machine Tool Co. Ltd.

Mr. P. F. Thorpe, B.Sc.(Eng.), Associate Member, has taken up a position with Soag Machine Tools Ltd., London, as Manager: Production and Engineering. He was formerly Works Manager at Woodfield Rochester Ltd., Kent.

Mr. E. Walker, Associate Member, has taken up an appointment as Mechanical Engineer with the Nitrate Corporation of Chile Ltd.

Mr. J. A. C. Williams, M.Sc., Associate Member, whilst retaining his present position as Principal of the College of Aeronautical and Automobile Engineering, has been appointed Director of The Aeronautical Educational Trust Ltd.

Mr. R. B. A. Wright, Associate Member, has relinquished his position with The de Havilland Engine Co. Ltd., and has taken up an appointment as General Works Manager, with The Bifurcated and Tubular Rivet Co. Ltd., Aylesbury, Bucks.

Mr. B. L. Hart, Associate, has recently been appointed Principal of the Computer Application Training Establishment of International Computers and Tabulators Ltd.

Mr. R. I. Archibald, Graduate, has taken up a position as Planning Engineer with Kolster-Brandes Ltd., St. Leonards-on-Sea.

Mr. B. Collier, Graduate, has been appointed Production Engineer at the Dumbarton Works of Dewrance & Co. Ltd.

Mr. R. Kelly, Graduate, has taken up the position of Production Supervisor with the General Electric Co., Semi-conductor Division. Mr. Kelly was formerly Planning Engineer at Cox & Co. (Watford) Ltd.

Mr. S. S. Lota, Graduate, is now a Design Draughtsman (Jig and Tools), with T. E. Millington Eng. Co. Ltd., Wolverhampton.

Mr. D. T. Roberts, Graduate, has relinquished his position with Bristol Siddeley Engines Ltd., Sunderland, to take up an appointment as a Methods Engineer with The North Eastern Marine Engineering Co. Ltd., Wallsend, Northumberland.

Mr. J. Thompson, Graduate, has relinquished his post as a Methods Engineer with Joseph Lucas (Electrical) Ltd., and has taken up an appointment as Industrial Engineer with Reynolds T. I. Aluminium Ltd., at their Redditch Works.

Mr. J. N. Warren, Graduate, has taken up an appointment as an Instrumentation Draughtsman with Vickers-Armstrongs (Aircraft) Ltd., Weybridge.

Mr. P. D. Mitchell, Graduate, formerly Assistant Sales Manager of Polypenco Ltd., is now Technical Sales Manager responsible for technical sales development, new product research and general sales promotion. He was formerly Planning Engineer with The de Havilland Aircraft Co. Ltd.

"LOST" MEMBERS

Correspondence and journals sent to the following members are being returned to the Institution marked " Not Known " or " Gone Away ". It would be appreciated if these members, or anyone knowing their present addresses, would get in touch with the Records Department at 10 Chesterfield Street, Mayfair, London, W.1.

J. R. Smith, Stud.I.Prod.E.,
c/o 84 Woodlands Road,
Springfield,
Birmingham, 11.

J. I. Goddard Watts, Grad.I.Prod.E.,
3B The Avenue,
Acocks Green,
Birmingham, 27.

G. B. Lee, Grad.I.Prod.E.,
85 Allens Road,
Handsworth,
Birmingham, 18.

G. Mitchell, Grad.I.Prod.E.,
46 Driffold,
Sutton Coldfield,
Warwicks.

B. H. Tummey, Grad.I.Prod.E.,
Chesham,
5 Folly Lane,
Hereford.

A. Johnson, A.M.I.Prod.E.,
215 Jayshaw Avenue,
Great Barr,
Birmingham, 2A.

A. D. Lane, A.M.I.Prod.E.,
9 Kempson Avenue,
Wylde Green,
Sutton Coldfield,
Warwicks.

H. Speed, A.M.I.Prod.E.,
207 Stechford Road,
Ward End,
Birmingham, 8.

Reginald Taylor, A.M.I.Prod.E.,
Andrews Components Ltd.,
157 Moseley Road,
Birmingham.

Richard Lloyd Ltd.,
Oliver Street,
Birmingham, 7.

J. F. P. Parsons,
Richard Lloyd Ltd.,
Oliver Street,
Birmingham, 7.

F. L. Brindley, Stud.I.Prod.E.,
24 Cwa Road,
Waunllyd,
Mon.

G. F. F. Ottley, A.M.I.Prod.E.,
Chevin,
Treverva,
Penryn,
Cornwall.

Major-General W. F. Hasted, C.B.E.,
M.I.Prod.E.,
Bayside,
Appledore,
Bideford, Devon.

C. Payne, Grad.I.Prod.E.,
6 Coral Close,
Broad Lane,
Coventry.

K. H. Davison, Grad.I.Prod.E.,
23 Spinney Road,
Chaddesden,
Derby.

R. Grant, M.I.Prod.E.,
50A Frederick Street,
Edinburgh, 1.

J. J. McGowan, Stud.I.Prod.E.,
166 Dorman Side Road,
Glasgow, S.W.3.

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Stud.I.Prod.E.,
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Collins, J. C. "**Radioactive Wastes: Their Treatment and Disposal.**" *London, Spon.,* 1960. 339 *pages. Illustrations. Diagrams.* 55s.

The first part of the book explains the problems which have to be understood when dealing with radioactive materials; the second deals with the treatment and disposal of liquid and gaseous radioactive materials.

Darwin, G. E. and Buddery, J. H. "**Beryllium.**" *London, Butterworths Scientific Publications,* 1960. 392 *pages. Illustrations. Diagrams.* (Metallurgy of the rarer metals series.) 70s.

Beryllium was until recently, considered mainly as an alloying element, particularly of copper, and although this still represents about 80% of its applications, it has recently assumed importance in nuclear and aircraft engineering. This book is — like others in the series — a compendium of recent information. It includes good bibliographies.

Contents: Occurrence, world resources and uses of beryllium — The production of beryllium oxide from Beryl — Beryllia — Production of beryllium metal — Fabrication — Physical properties — Chemical reactivity — Alloys and compounds — A minor alloying addition — Nuclear properties — Health hazards and their control — Appendix. The determination of oxygen in beryllium.

Eary, Donald F. and Reed, Edward A. "**Techniques of Press Working Sheet Metal: An Engineering Approach to Die Design.**" *London, Staples Press,* 1960. 472 *pages. Illustrations. Diagrams.* 55s.

First published by Hawthorne Books Inc. in 1957. The authors, both of the Industrial Engineering Department fo General Motors Institute, attempt to provide the theoretical background necessary to the technical college student, and the practical information required by those engaged in sheet metal working.

Contents: Theory of cutting sheet metal — Sheet metal cutting formula — Sheet metal cutting operations — Theory of forming sheet metal — Sheet metal formula — Sheet metal forming operations — Theory of drawing sheet metal — Sheet metal drawing formula — Sheet metal drawing operations — Miscellaneous pressworking operations — Types of die construction — Press types and nomenclature — Mechanical handling devices — Stock layout techniques — Processing of sheet metal parts — Die details: function and nomenclature — Standard die details and design styles — Die design techniques — Selection of die steels — Drafting techniques — Appendix (General Motors Standards. Tool Steel information).

Gloucester Railway Carriage and Wagon Co. Ltd., Gloucester. "**A History of the Gloucester Railway Carriage and Wagon Company.**" *London, Weidenfeld and Nicholson,* 1960. 64 *pages. Photographs.*

This centenary volume of the Gloucester Railway Carriage and Wagon Company will instruct those interested in the history of British industry, and its many excellent photographs of the company's products will give pleasure to romantics and railway enthusiasts. There are photographs of railway carriages and iron wagons of the sixties; a prison van for the Tamoff Saratoff Railway (1869); A luxury coach for South America (1890); early horse-drawn and motor 'buses; victorias; gigs; a Churchill tank; and some the light alloy and railway coaches of the 1950's.

Grant, Eugene L. and Ireson, W. Grant. "**Principles of Engineering Economy.**" (4th Edition). *New York, Ronald Press,* 1960. 574 *pages.* 65s.

Deals with the principles of decision making and the techniques needed for making decisions about the acquisition and retirement of capital goods by industry and government. Because engineers make many such decisions and make recommendations for many others, the body of principles and techniques involved has become known as "engineering economy". The book could be used as a text book for students of economics and engineering, although the former would probably find the subject matter more familiar. There are questions appended to each chapter.

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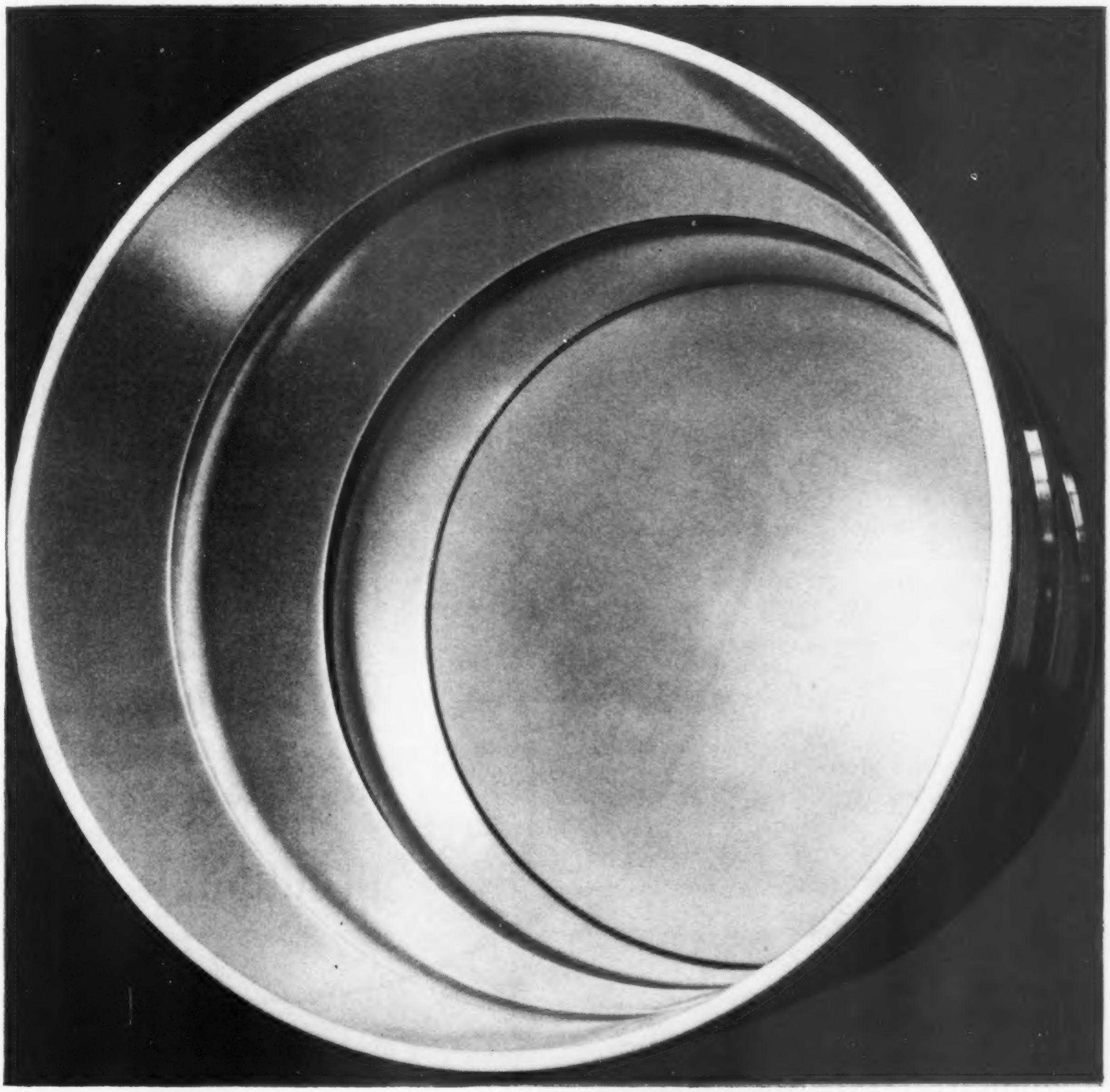

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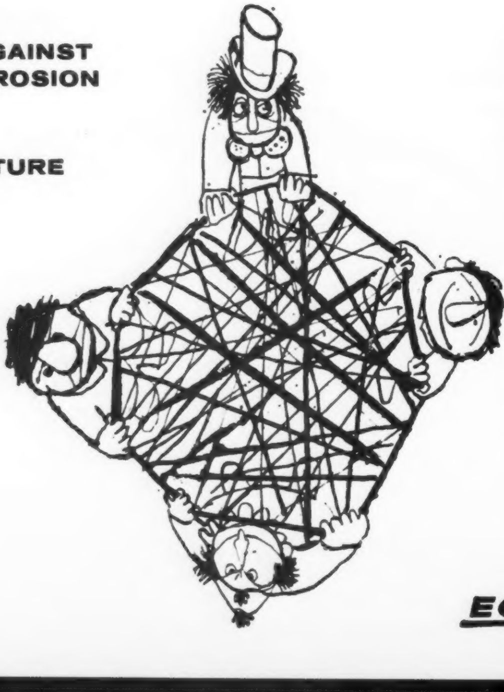

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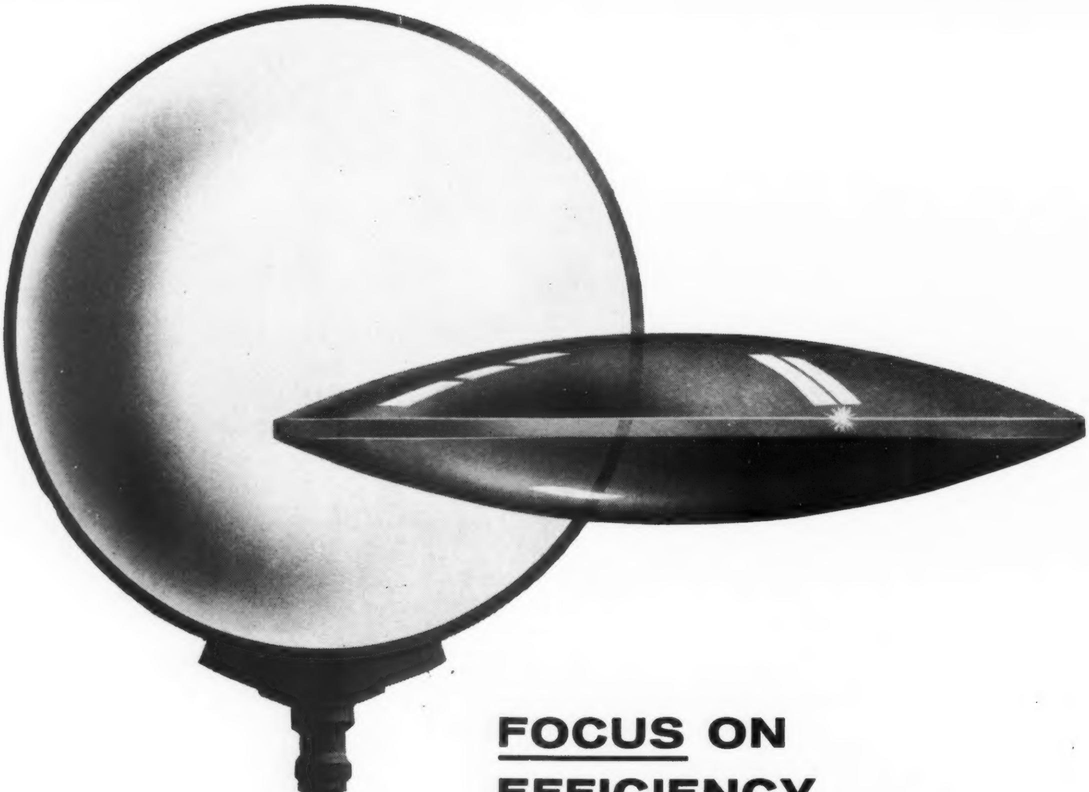

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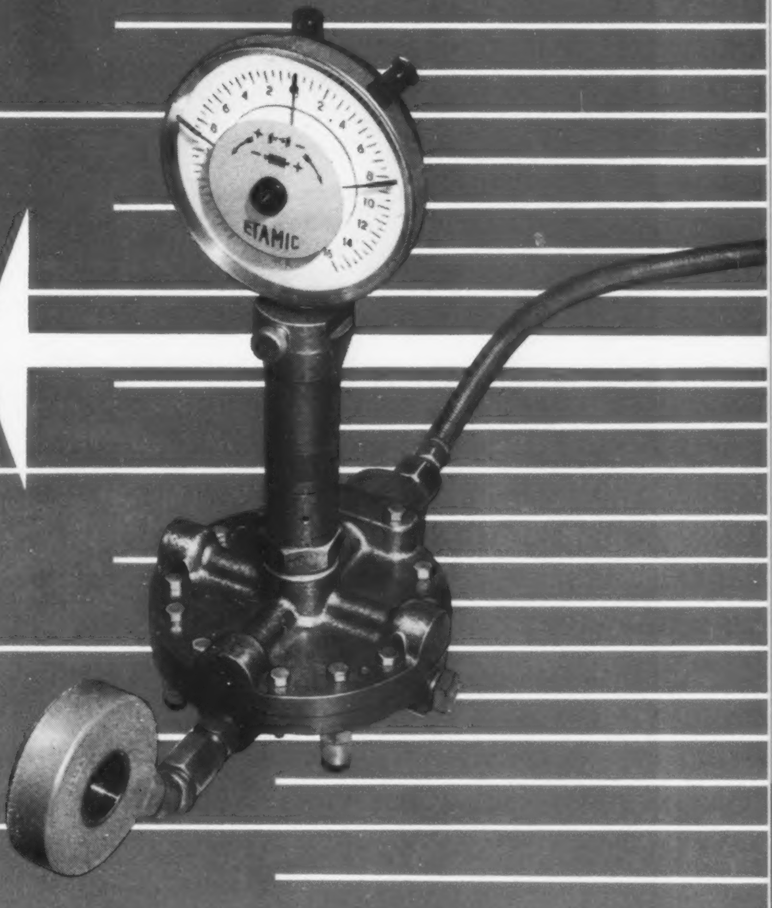

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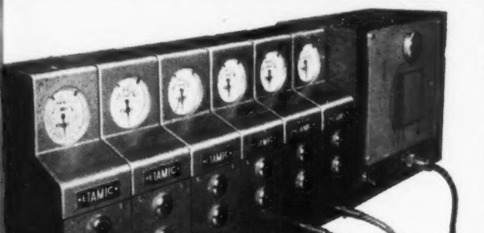

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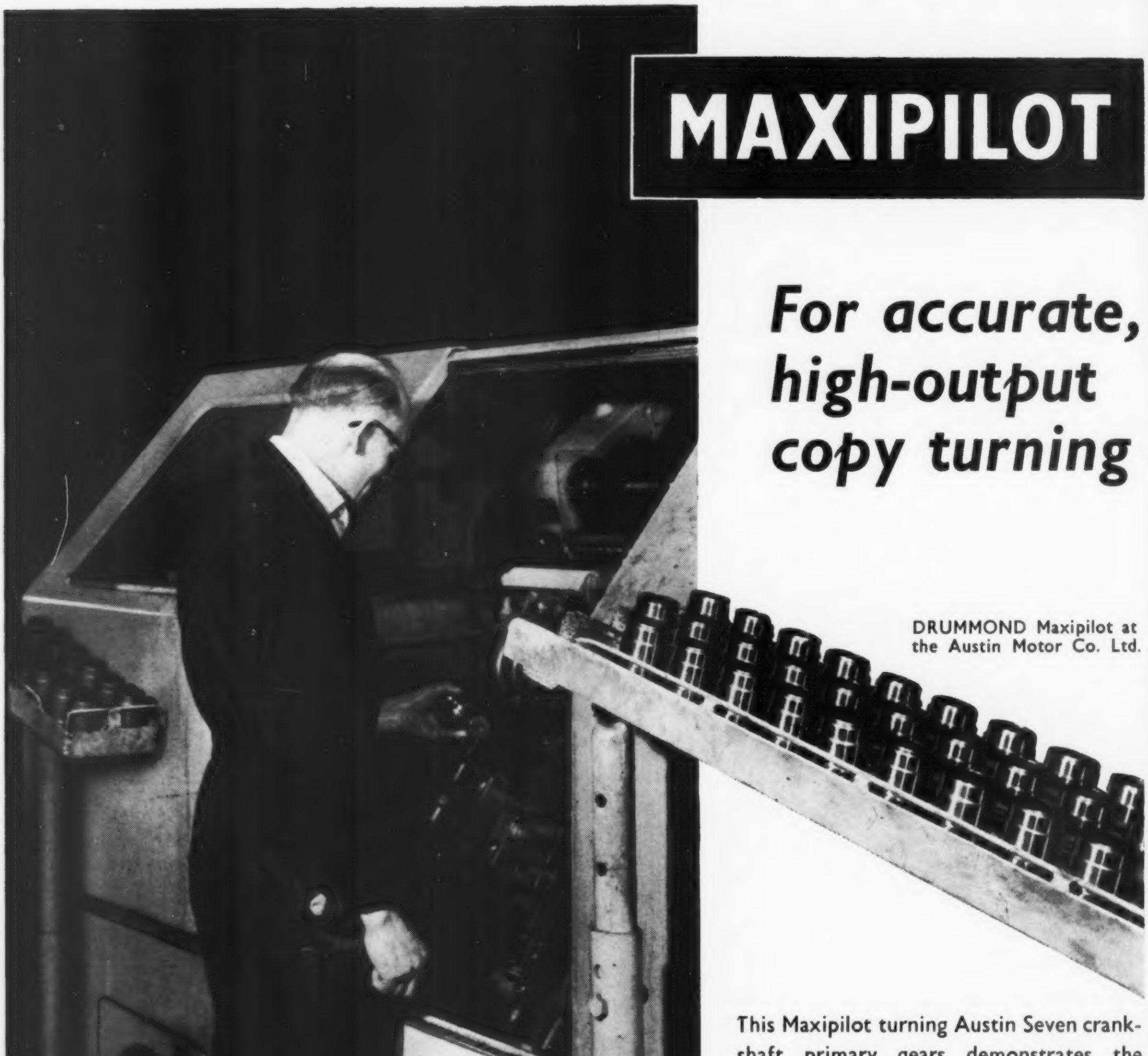

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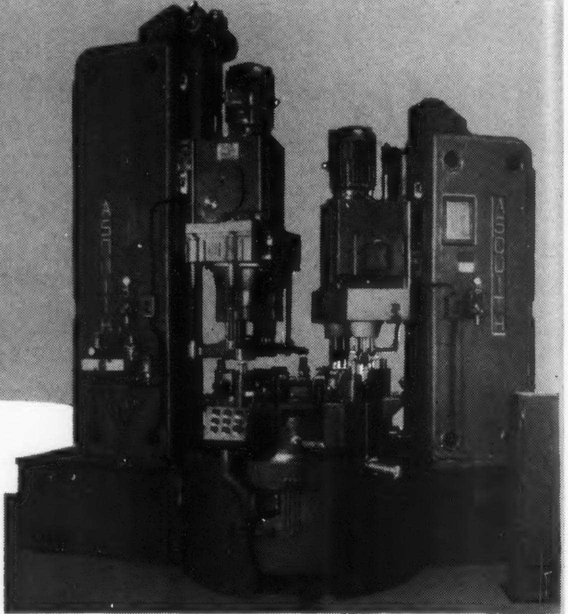

Asquith Five Station Rotary Transfer Machine for drilling, reaming and tapping operations on a Vauxhall hub component.

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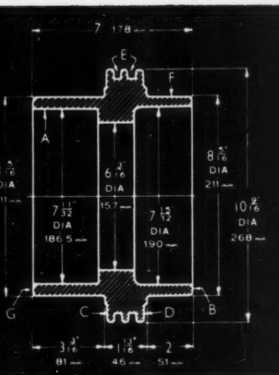

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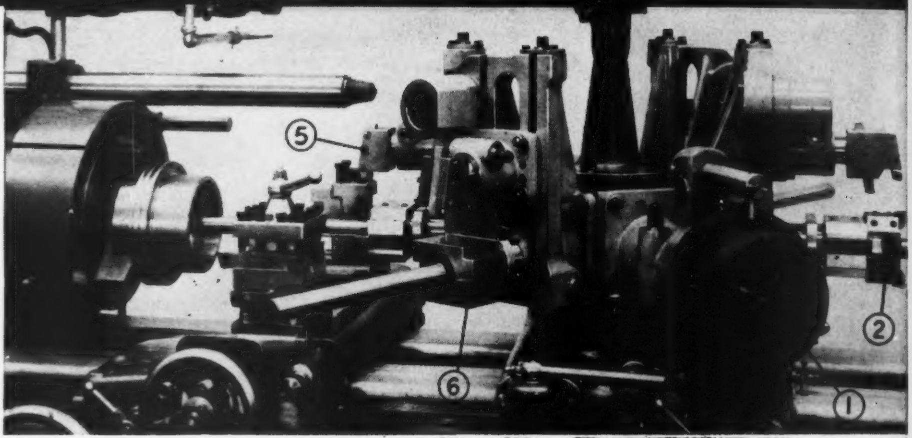
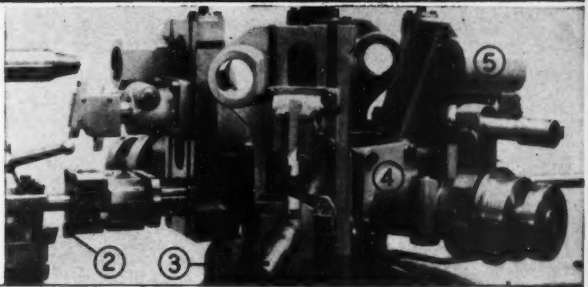


No. 8 TURRET LATHE

Code Word : **Covhylet**

Equipped with 15" — 3-Jaw Tudor Chuck.

Total Floor to Floor Time : 22 mins.



DESCRIPTION OF OPERATION	Tool Position: Hex. Turret	Tool Position: Cross-slide	Spindle Speed R.P.M.	Max. Cutting Speed: Feet per min.	Max. Cutting Speed: Metres per min.	Feed: Cuts per inch	Feed: m/m. per rev.
1st Process							
1. Grip internally in "A" (using loading attachment)	1	—	—	—	—	—	—
2. Rough face "B"	—	S.T.1	102	229	69·7	98	·259
3. Rough knee turn $10\frac{9}{16}$" & $8\frac{5}{16}$" dias. and rough bore $7\frac{15}{32}$" & $6\frac{3}{16}$" dias.	2	—	84	238	72·5	136	·187
Face "D"	—	S.T.2	84	238	72·5	270	·094
4. Form grooves "E"	—	Rear	102	282	89	270	·094
5. Finish knee turn $10\frac{9}{16}$" & $8\frac{5}{16}$" dias. and finish bore $7\frac{15}{32}$" & $6\frac{3}{16}$" dias.	3	—	132	365	110·2	136	·187
6. Finish face "B"	—	S.T.2	172	375	114	136	·187
7. Remove component (using attachment)	4	—	—	—	—	—	—
2nd Process							
1. Chuck on "F" (using attachment)	4	—	—	—	—	—	—
2. Rough face "G"	—	S.T.1	102	229	69·7	98	·259
3. Rough knee turn $8\frac{5}{16}$" dia. and rough bore $7\frac{11}{32}$" dia.	5	—	102	229	69·7	136	·187
Face "C"	—	S.T.2	102	282	89	270	·094
4. Finish knee turn $8\frac{5}{16}$" dia. and finish bore $7\frac{11}{32}$" dia.	6	—	172	375	114	136	·187
Finish face "G"	—	S.T.2	172	375	114	136	·187
5. Remove component (using attachment)	4	—	—	—	—	—	—

'PRELECTOR' Combination Turret Lathes with Preselective speed-changing.

TURRET LATHES with capacities up to 35 in. swing over bed

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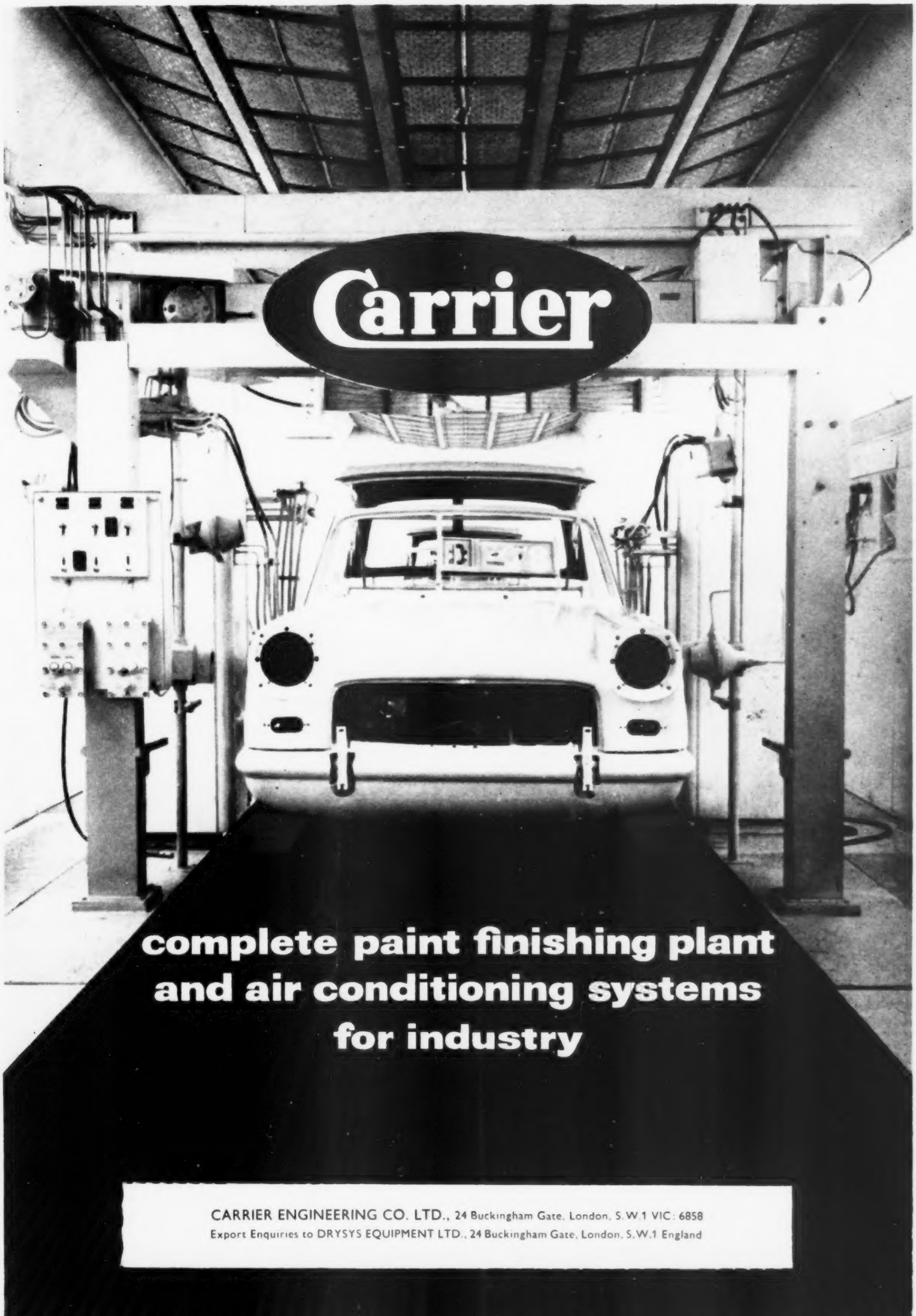
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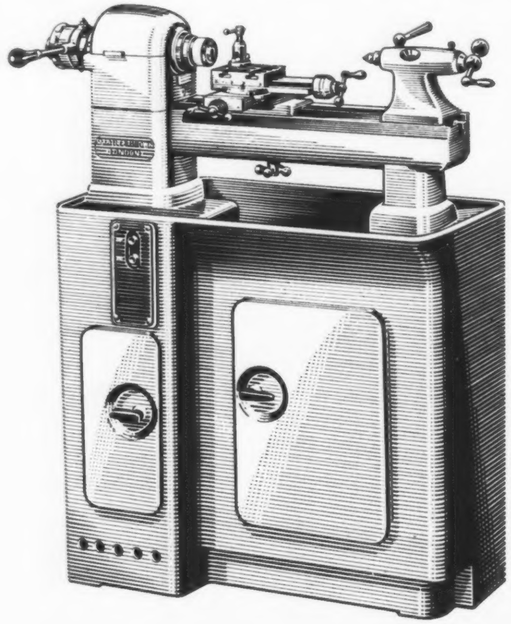

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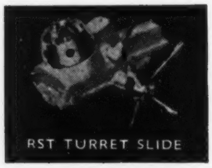

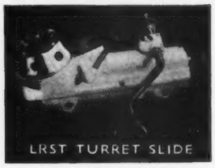

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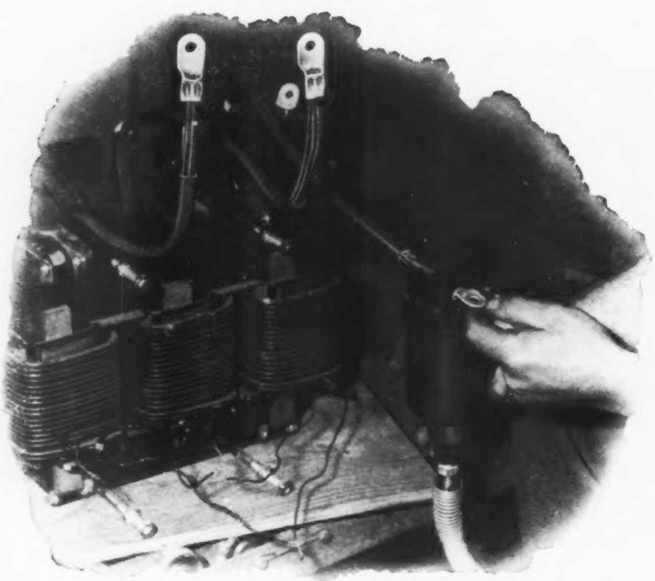

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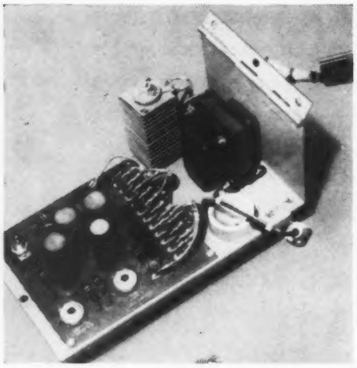
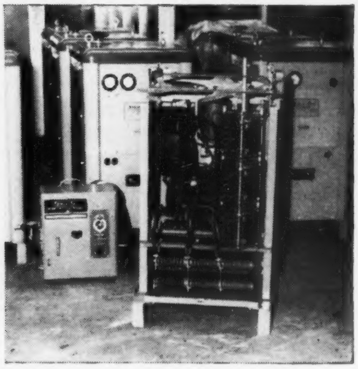


Electronic control unit showing *Faston connection to printed circuit panel

Main transformer as used on Rowen-Arc Welding Unit RCP 500.



Rowen-Arc Welding Unit RCP 500.

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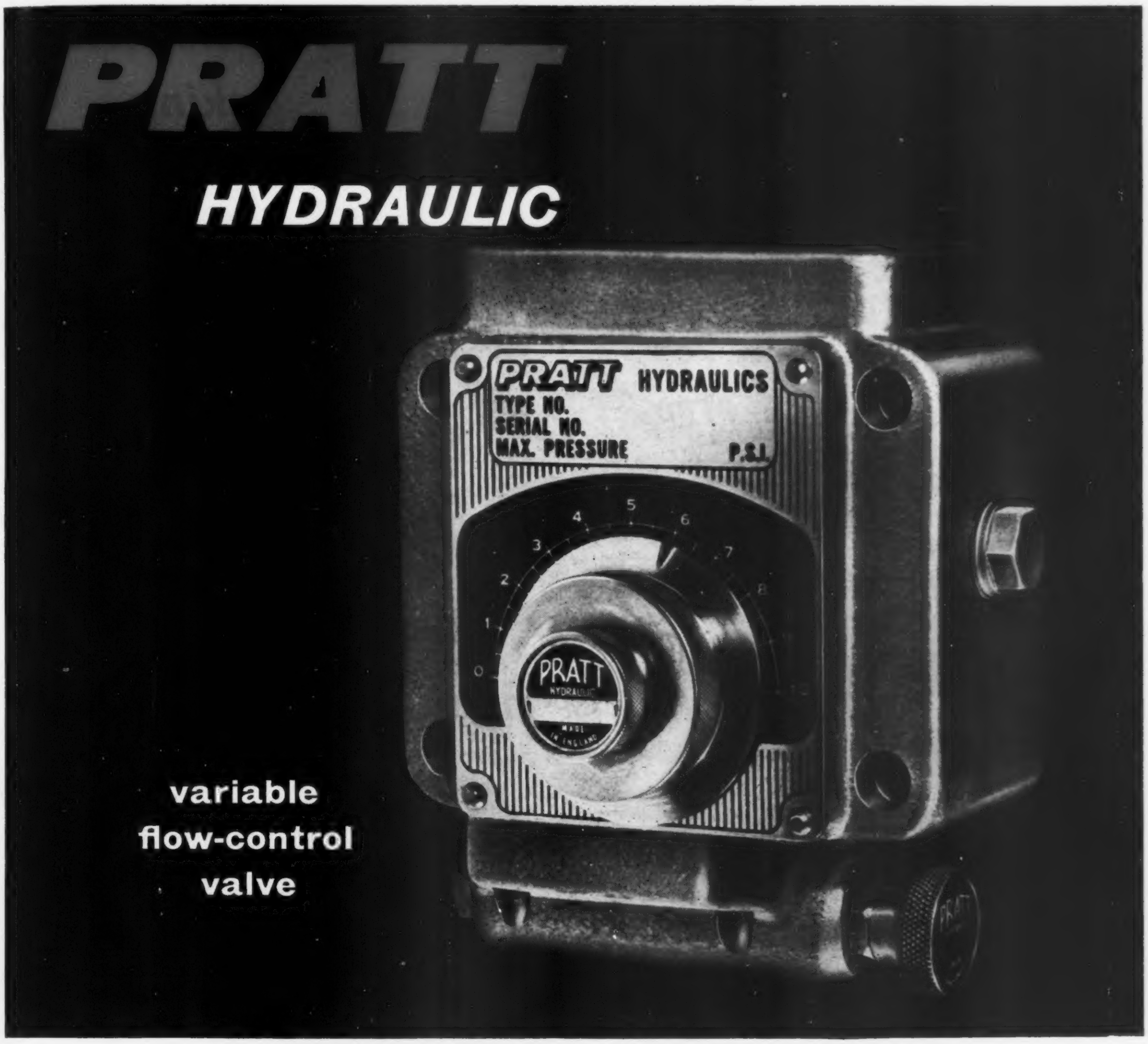

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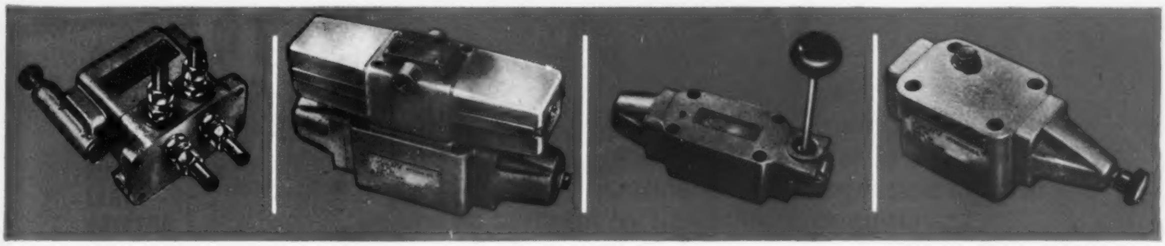

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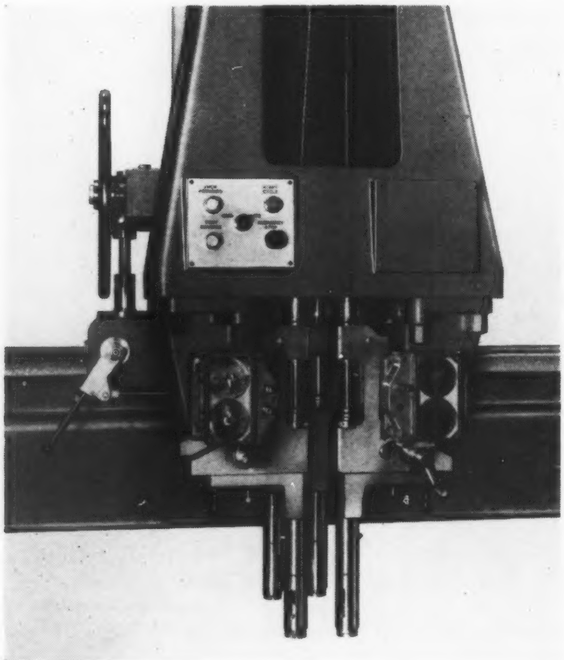

On the left is a close-up of the drilling head showing dials for setting position of each spindle.

Below is a view of the complete machine with one multi-head.

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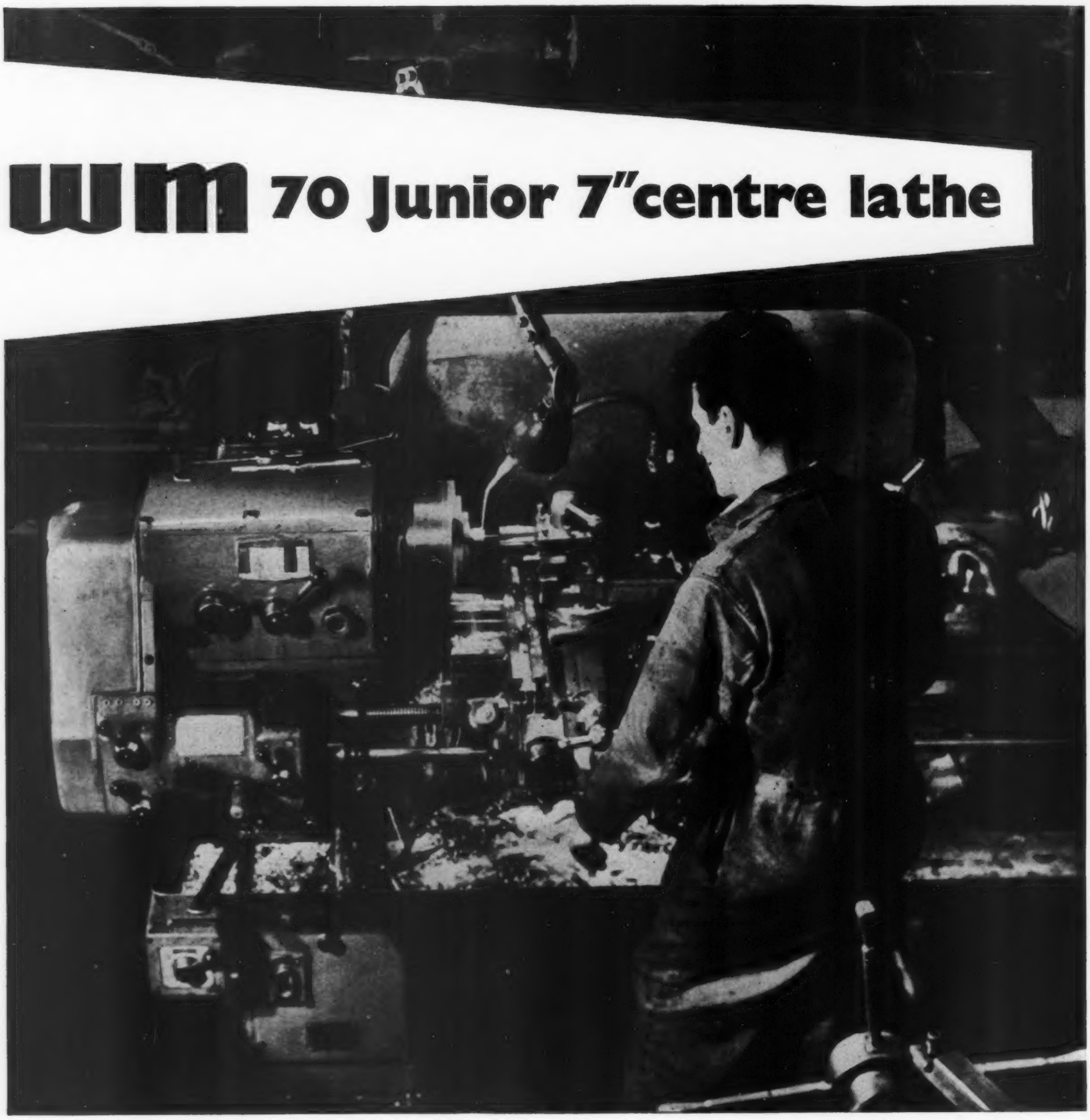

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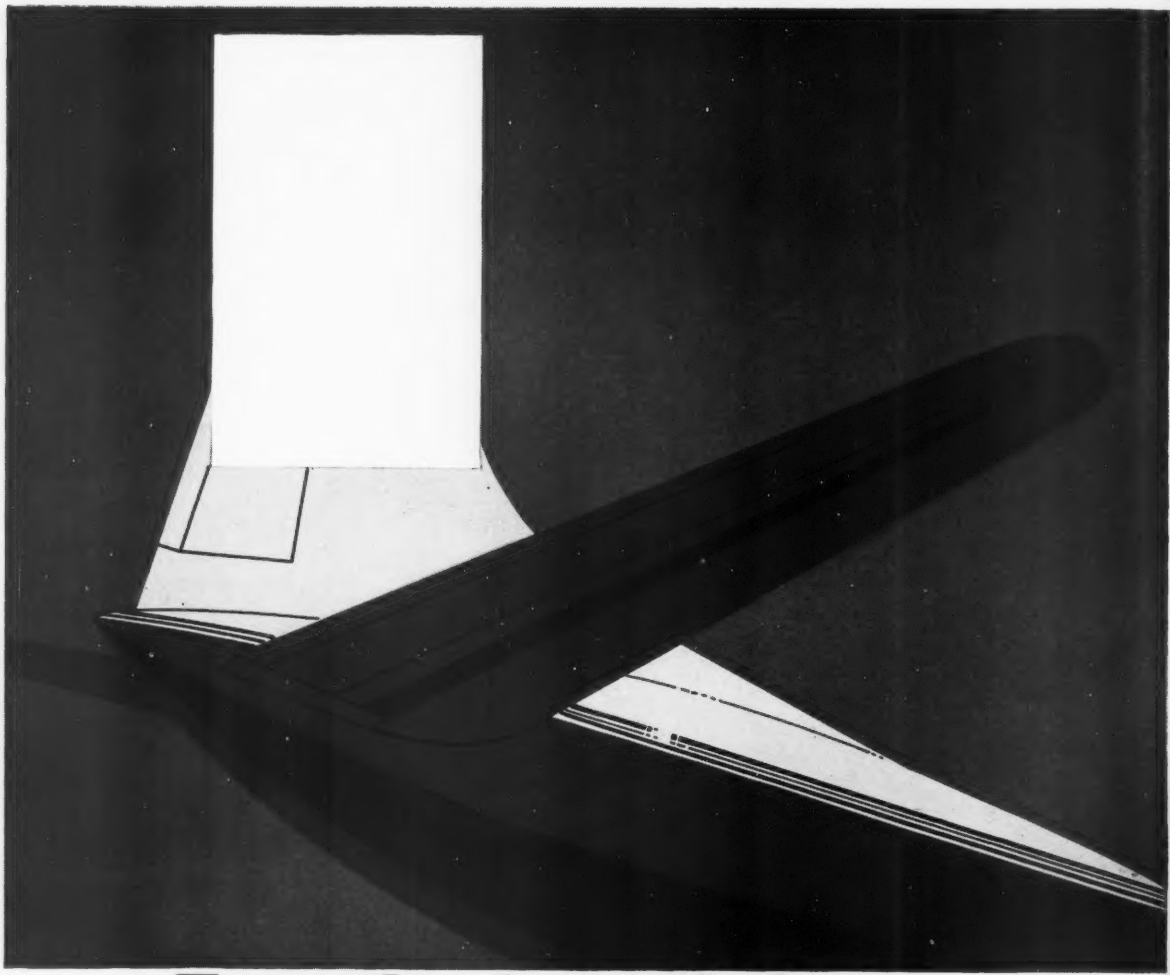

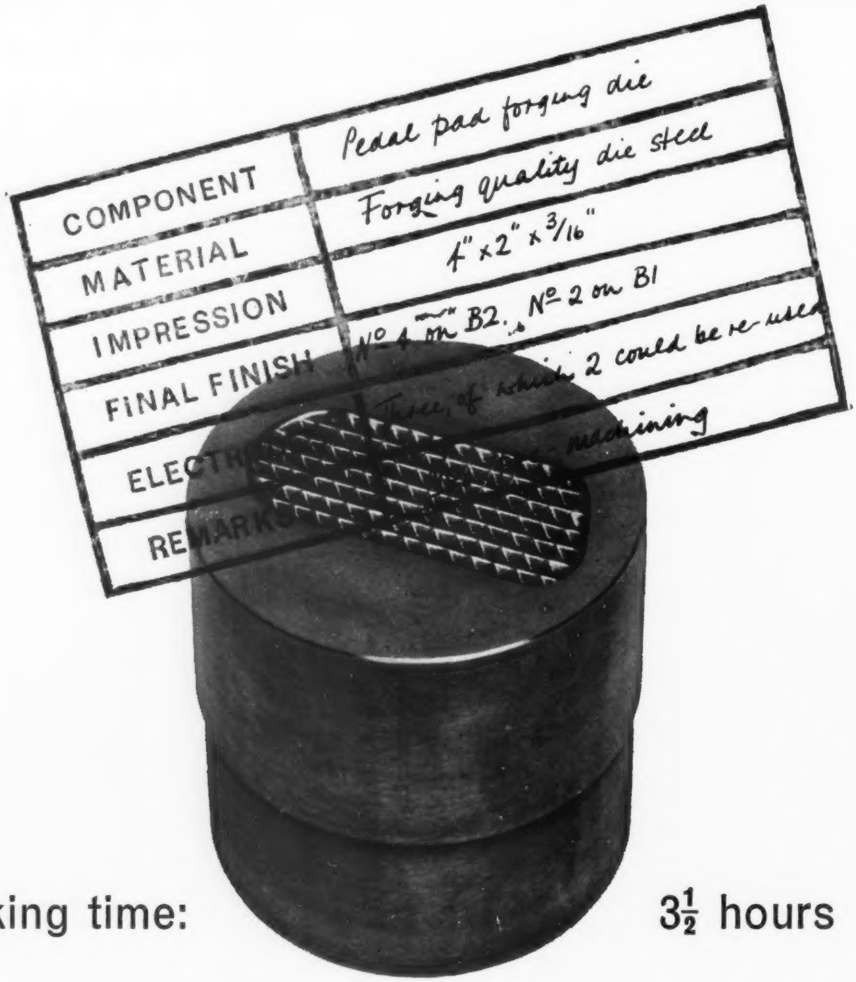

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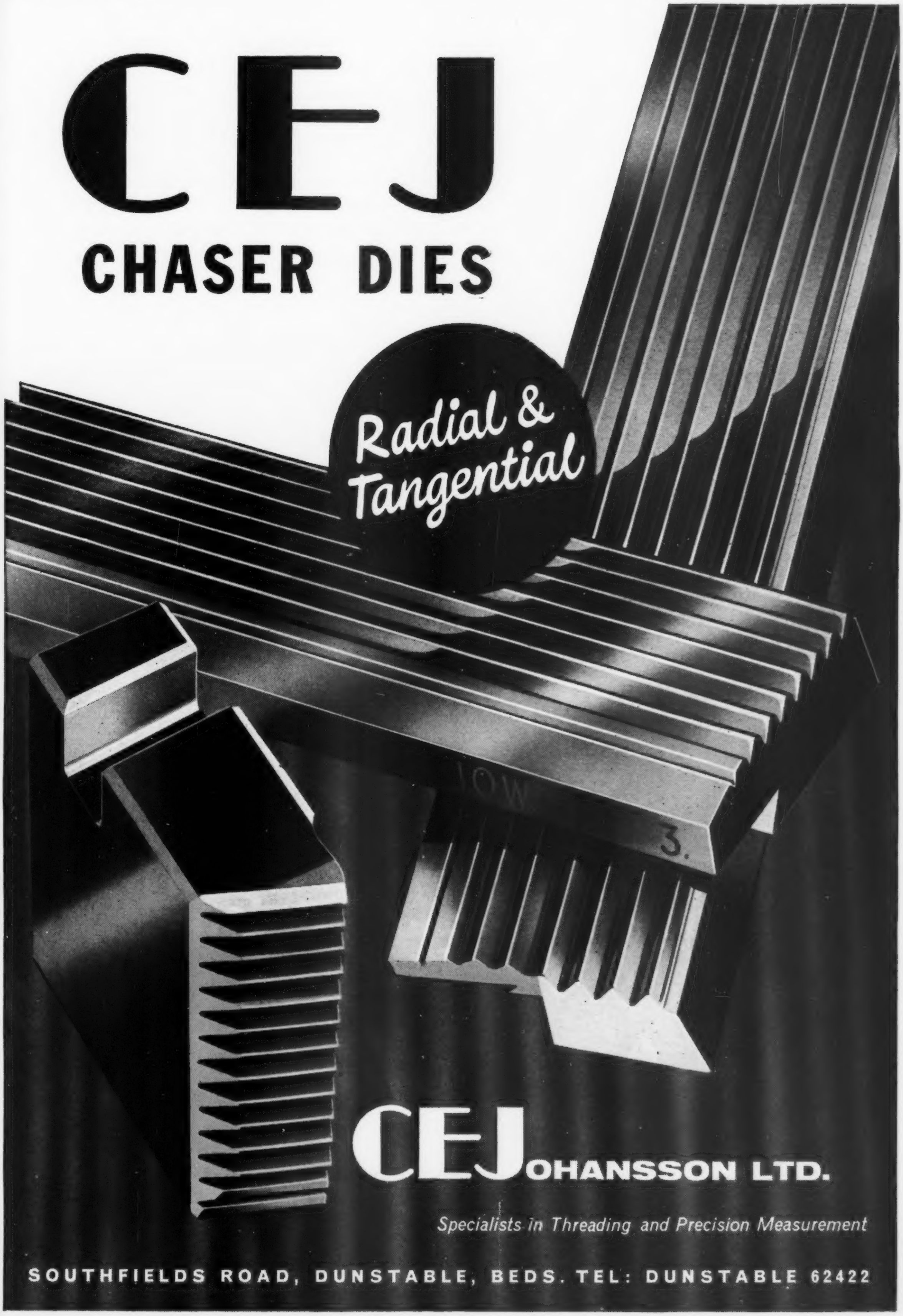
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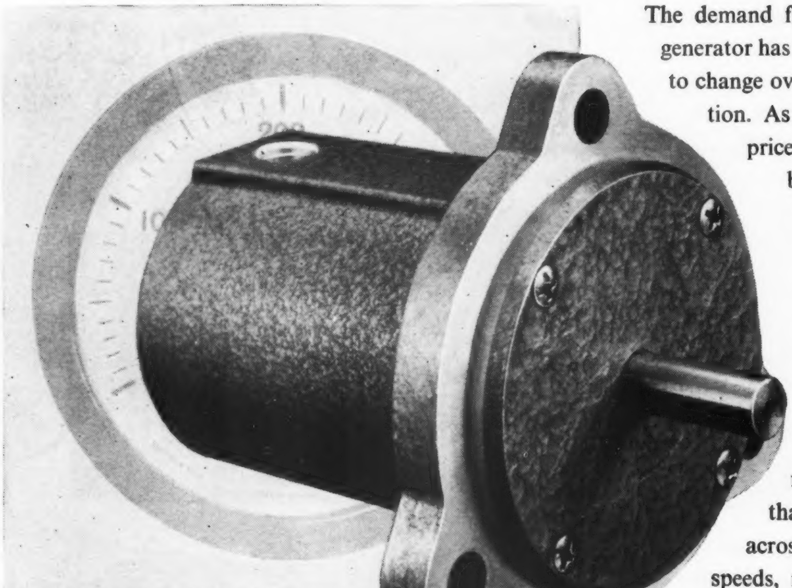

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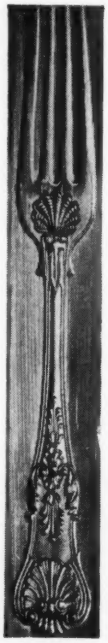

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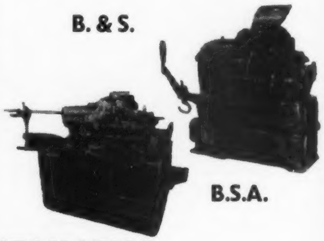

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C.V.A.

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✱ May we visit your works and quote for rebuilding your machine?

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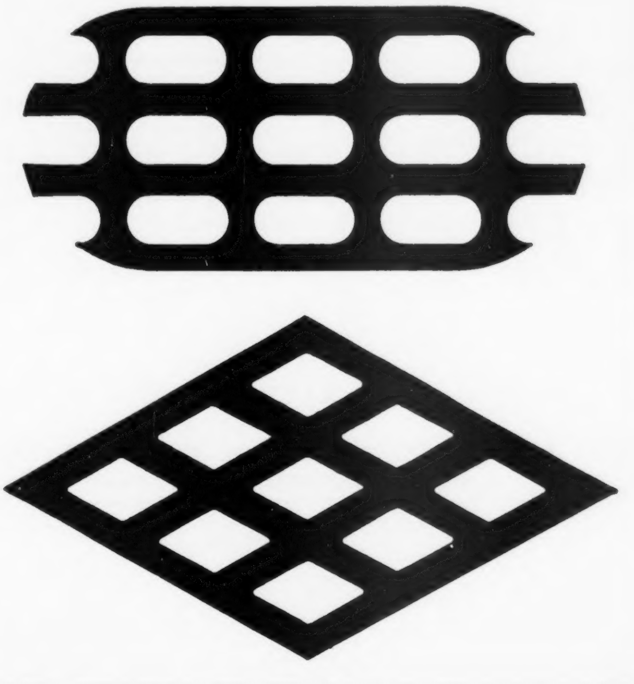
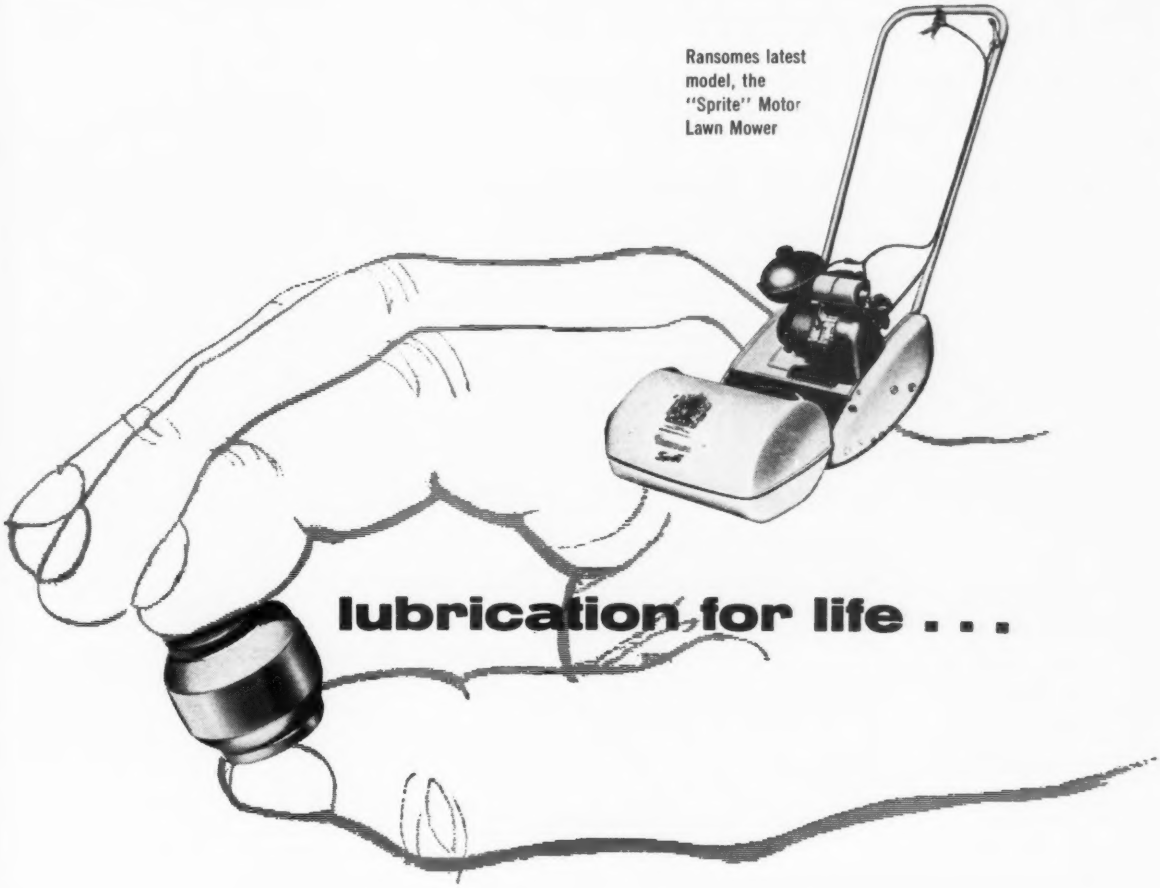
(H. E. SLAWSON, M.B.E., M.I.P.E., Man. Dir.) Tel: MELBOURNE 232





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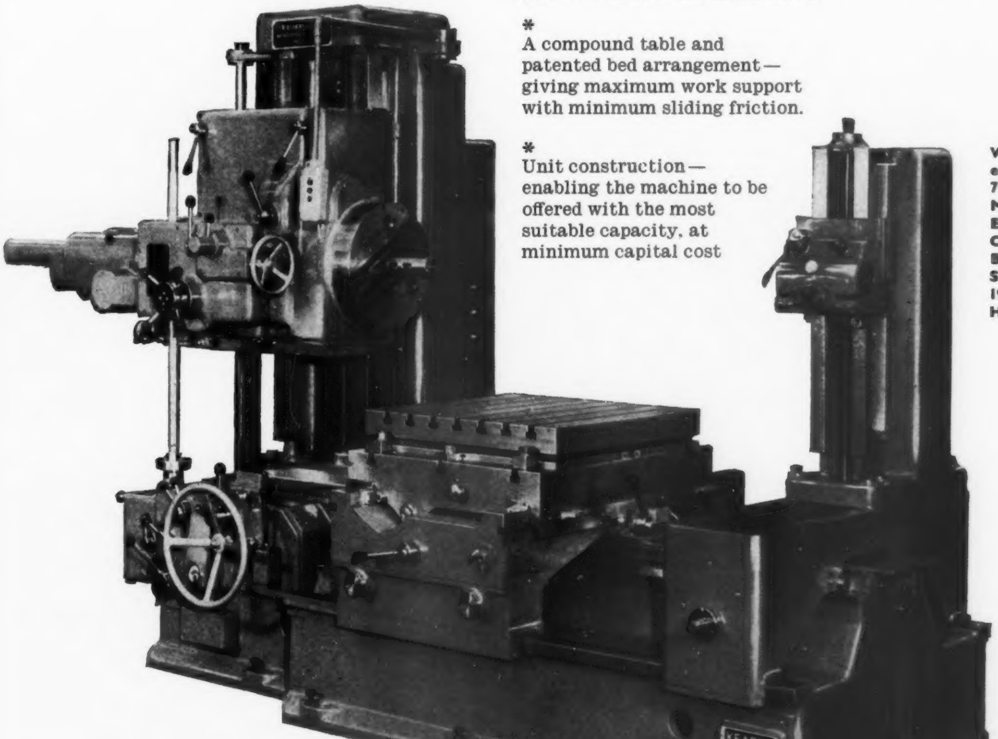

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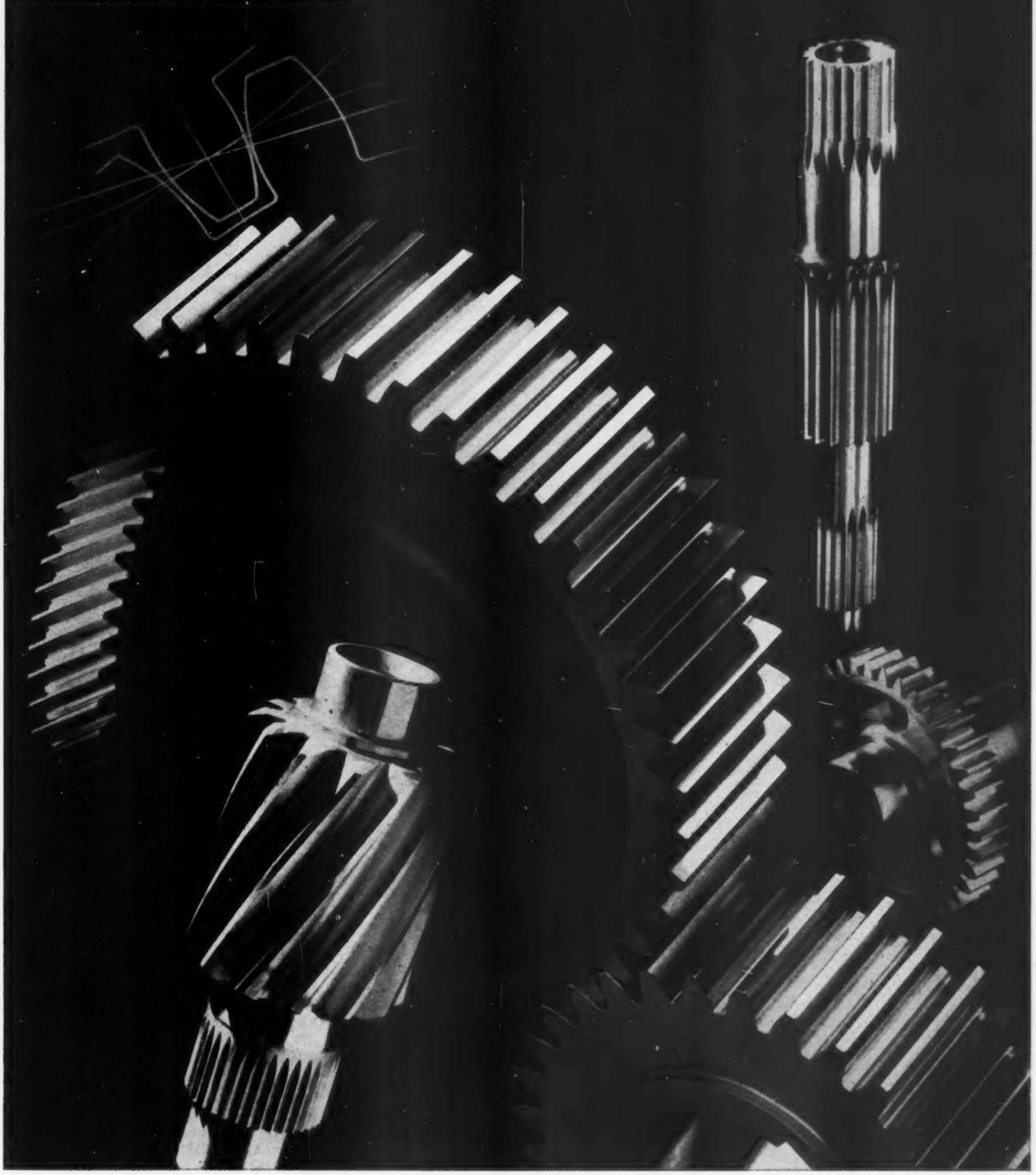

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